The Engineering Staff of
TEXAS INSTRUMENTS INCORPORATED
Components Group

The Optoelectronics Data Book

for Design Engineers

TEXAS INSTRUMENTS
INCORPORATED

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THE OPTOELECTRONICS DATA BOOK

Few people in the electronics industry realize that optoelectronics technology has a history which precedes the invention of the integrated circuit. It is also a relatively unknown fact that Texas Instruments was a pioneer in the development and manufacture of some of the first optoelectronic components, viz infrared detectors and photovoltaic solar cells, back in 1957.

During the past fifteen years TI has continued to develop and build optoelectronic devices and assemblies for end applications in the space, military, computer, industrial, and consumer industries. TI opto devices, like the 1N2175 photo-duo-diode which was introduced in 1959 and is still popular, have helped to revolutionize the industry and to make it easier for the design engineer to accomplish his job.

In addition to offering the most experience, TI also provides the most complete line of standard opto products in the world. This ensures that design engineers can obtain more answers to questions involving circuitry and operating conditions by contacting TI.

If the most experience and the largest product line are not enough, TI also offers a locally based field sales engineering staff to assist design engineers. In most major cities throughout the U.S. and other countries there is a field sales engineer who has been trained as a specialist in opto products. His job is to provide the right product recommendations after considering all of the facts.

To complete the service aspect, TI has a world-wide distributor network which stocks almost 100 standard opto devices and assemblies. This means that design engineers can obtain fast delivery on small quantities required for initial circuit evaluation and purchasing departments can be assured of a local source of supply for production quantities.

It is the purpose of this data book to better acquaint both engineers and buyers with TI opto products and capabilities. It offers the user a categorized listing of optoelectronic data sheets, application reports, and product bulletins for more than 125 standard devices. Each product section has a quick reference quide which lists the key electrical parameters and features for products in that section.

To further assist the user, there is a competitive cross-reference guide which lists almost 500 optoelectronics devices built by other manufacturers, along with the nearest TI equivalent devices. There is a glossary of optoelectronic terminology to answer questions on optoelectronic terms and phrases. Finally, we have referenced many TI integrated circuit and transistor part numbers which are compatible with TI opto products to make the task of interfacing easier.

We feel that this data book is the most complete publication of its kind. It was compiled and edited with the objective of making your job easier.

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GLOSSARY
OPTOELECTRONIC TERMS AND DEFINITIONS

Units of Measurement

Symbol	Unit	Note
A	ampere	
Å	angstrom	1 Å = 10^{-10} m = 10^{-4} µm = 0.1 nm
cd	candela	1 cd = 1 lm/sr
°C	degree Celsius	
°K		See K
ft	foot	
fc	footcandle	The equivalent unit lm/ft^2 is preferred
fL	footlambert	1 fL = $(1/\pi)$ cd/ft^2 = 3.4263 cd/m^2
Hz	hertz	
in	inch	
K	kelvin	Formerly °K, degree Kelvin
L	lambert	
lm	lumen	
lx	lux	1 lx = 1 lm/m^2
m	meter	
µ	micron	The equivalent unit µm is preferred
nt	nit	1 nt = 1 cd/m^2
Ω	ohm	
s	second	
sr	steradian	
sb	stilb	1 sb = 1 cd/cm^2
V	volt	
W	watt	

Metric Multipliers

Many of the preceding unit symbols can be combined with the metric multipliers which follow.

Symbol	Prefix	Multiple
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}
h	hecto	10^{2}
da	deka	10
d	deci	10^{-1}
c	centi	10^{-2}
m	milli	10^{-3}
µ	micro	10^{-6}
n	nano	10^{-9}
p	pico	10^{-12}
f	femto	10^{-15}
a	atto	10^{-18}

Terms and Definitions

Avalanche Photodiode (APD)

A photodiode designed to take advantage of avalanche multiplication of photocurrent. As the reverse-bias voltage approaches the breakdown voltage, hole-electron pairs created by absorbed photons acquire sufficient energy to create additional hole-electron pairs when they collide with substrate atoms; thus a multiplication effect is achieved.
NOTE: APD's are especially suited for low-noise and/or high-speed applications.

Beam-Lead Phototransistor

A phototransistor chip with thick-film leads formed on the chip which project cantilever-style beyond the chip periphery for attachment to a separate substrate.
NOTE: When assembled into arrays and mounted on a ceramic substrate, beam-lead phototransistor arrays offer accurate spacing on centers too close for conventional discrete packages and too far apart for monolithic arrays; see TI Bulletin CB-128 for further information.

Brightness

See Luminance

Color Temperature

The temperature of a blackbody whose radiation has the same visible color as that of a given non-blackbody radiator.
TYPICAL UNIT: K (formerly °K).

Conversion Efficiency (of a Photoemissive Device)

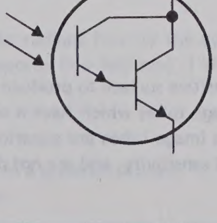
The ratio of maximum available luminous or radiant flux output to total input power.

Dark Current (I_D)

The current that flows through a photosensitive device in the dark condition.
NOTE: The dark condition is attained when the electrical parameter under consideration approaches a value which cannot be altered by further irradiation shielding.

Darlington-Connected Phototransistor

A phototransistor the collector and emitter of which are connected to the collector and base, respsectively, of a second transistor. The emitter current of the input transistor is amplified by the second transistor and the device has very high sensitivity to light.
GRAPHIC SYMBOL:



D-C Fan-Out

A term characterizing the driving capability of an output; specifically, the number of inputs of a specified type that can be driven simultaneously by the output.

D-C Transfer Ratio (of an Optically Coupled Isolator)

The ratio of the dc output current to the dc input current.

Delay Time (t_d)

The time interval from the point at which the leading edge of the input pulse has reached 10% of its maximum amplitude to the point at which the leading edge of the output pulse has reached 10% of its maximum amplitude.

Electroluminescence

The direct conversion of electrical energy into light.

Emission Beam Angle Between Half-Power Points (θ_{HP})

The angle centered on the optical axis of a light-emitting diode within which the relative radiant power output or photon intensity is not less than half of the maximum output or intensity.

Fall Time (t_f)

The time duration during which the trailing edge of a pulse is decreasing from 90% to 10% of its maximum amplitude.

Forward Voltage (V_F)

The voltage across a semiconductor diode associated with the flow of forward current. The p-region is at a positive potential with respect to the n-region.

Gain-Bandwidth Product (of an Avalanche Photodiode)

The gain times the frequency of measurement when the device is biased for maximum obtainable gain.

Hexadecimal Display

A solid-state display capable of exhibiting numbers 0 through 9 and alpha characters A through F.
NOTE: The TIL311 is a hexadecimal display with an integral TTL circuit which will accept, store, and display 4-bit binary data.

Illumination (E_v)

The luminous flux density incident on a surface; the ratio of flux to area of illuminated surface.
TYPICAL UNITS: lm/ft^2, $lx = lm/m^2$. $1\ lm/ft^2 = 10.764\ lx$

Image Tube

A camera tube which utilizes a photosensitive surface to produce an electron image and a video signal.
NOTE: TI manufactures solid-state image tubes which have a silicon-diode matrix consisting of 620,000 diodes per square centimeter. These VID-series image tubes are superior to conventional image tubes because they have higher sensitivity, extremely broad-band sensitivity, and are not damaged when subjected to high light levels up to $6 \times 10^7\ lm/ft^2$.

Infrared Emission

Radiant energy which is characterized by wavelengths longer than visible red, viz 0.78 μm to 100 μm.

Infrared Light-Emitting Diode

An optoelectronic device containing a semiconductor p-n junction which emits radiant energy in the 0.78-μm to 100-μm wavelength region when forward-biased. See light-emitting diode for graphic symbol.
NOTE: TI manufactures GaAs and GaAsP light sources which emit in the 0.82-μm to 0.94-μm portion of the near-infrared region. These light emitters are spectrally matched with TI silicon phototransistors and photodiodes.

Irradiance (H or E_e)

The radiant flux density incident on a surface; the ratio of flux to area of irradiated surface.
TYPICAL UNITS: W/ft^2, W/m^2. 1 W/ft^2 = 10.764 W/m^2.

Light

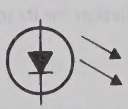
For the purpose of these definitions, radiant energy transmitted by wave motion with wavelengths from about 0.3 μm to 30 μm; this includes visible wavelengths (0.38 μm to 0.78 μm) and those wavelengths, such as ultraviolet and infrared, which can be handled by optical techniques used for the visible region. In more restricted usage, radiant energy within the limits of the visual spectrum.

Light Current (I_L)

The current that flows through a photosensitive device, such as a phototransistor or a photodiode, when it is exposed to illumination or irradiance.

Light-Emitting Diode (LED)

See infrared-light-emitting diode and/or visible-light-emitting diode.
GRAPHIC SYMBOL:



Luminance (L) (Photometric Brightness)

The luminous intensity of a surface in a given direction per unit of projected area of the surface as viewed from that direction.
TYPICAL UNITS: fL, cd/ft^2, cd/m^2. 1 fL = (1/π) cd/ft^2 = 3. 4263 cd/m^2.

Luminous Flux (Φ_V)

The time rate of flow of light.
TYPICAL UNIT: lm
NOTE: Luminous flux is related to radiant flux by the eye-response curve of the International Commission on Illumination (CIE). At the peak response (λ = 555 nm), 1 W = 680 lm.

Luminous Intensity (I_V)

Luminous flux per unit solid angle in a given direction.
TYPICAL UNIT: cd. 1 cd = 1 lm/sr.

Noise Equivalent Power (P_n, NEP) (of an Avalance Photodiode)

The broadband output noise voltage divided by the responsivity in volts/watt (or the broadband output noise current divided by the responsivity in amps/watt) and the square root of the noise bandwidth. Noise bandwidth is $\pi/2$ times the 3-dB bandwidth of the system.

Off-State Collector Current (of an Optically Coupled Isolator) ($I_{C(off)}$)

The output current when the input current is zero.

On-State Collector Current (of an Optically Coupled Isolator) ($I_{C(on)}$)

The output current when the input current is above a threshold level.
NOTE: An increase in the input current will usually result in a corresponding increase in the on-state collector current.

Optical Axis

A line about which the radiant-energy pattern is centered; usually perpendicular to the active area.

Optically Coupled Isolator (Optical Coupler, Transoptor)

An optoelectronic device consisting of a photoemissive device and a photosensitive device integrated into a single entity and intended for the transfer of a signal from the input to the output.
NOTE: As manufactured by Texas Instruments, these devices consist of a gallium arsenide light-emitting diode and a silicon phototransistor and provide high-voltage isolation between separate pairs of input and output terminals.

Optoelectronic Device

A device which detects and/or is responsive to electromagnetic radiation (light) in the visible, infrared, and/or ultraviolet spectral regions; emits or modifies noncoherent or coherent electromagnetic radiation in these same regions; or utilizes such electromagnetic radiation for its internal operation.

Photocurrent

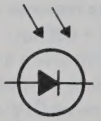
The difference beween light current (I_L) and dark current (I_D) in a photodetector.

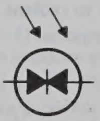
Photocurrent Gain (of an Avalanche Photodiode)

The ratio of photocurrent at high bias voltage to that at low bias voltage. (See also avalanche photodiode definition).

Photodiode

A diode which is used to detect light. A diode which has been optimized for light sensitivity.
GRAPHIC SYMBOLS:





NOTE: The photodiode is characterized by linearity between the input radiation and the output current. It has faster switching speeds than a phototransistor.

Photometric Axis

The direction from the source of radiant energy in which the measurement of photometric parameters is performed.

Photometric Brightness

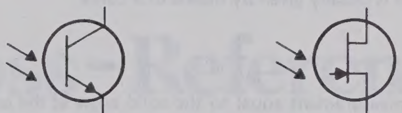
See Luminance.

Photon

A quantum (the smallest possible unit) of radiant energy; a photon carries a quantity of energy equal to Planck's constant times the frequency.

Phototransistor

A transistor (bipolar or field-effect) which is used to detect light. A transistor which has been optimized for light sensitivity.
NOTE: The base region or gate may or may not be connected to an external terminal.
GRAPHIC SYMBOLS:



Quantum Efficiency (of a Photosensitive Device)

The ratio of the number of carriers generated to the number of photons incident upon the active region.

Radiant Flux (Φ_e)

The time rate of flow of radiant energy.
TYPICAL UNIT: W

Radiant Pulse Fall Time (t_f)

The time required for a photometric quantity to change from 90% to 10% of its peak value for a step change in electrical input.

Radiant Pulse Rise Time (t_r)

The time required for a photometric quantity to change from 10% to 90% of its peak value for a step change in electrical input.

Responsitivity (N, $\overline{R}_m$)

The quotient of the rms value of the fundamental component of the electrical output of the detector to the rms value of the fundamental component of the input radiation power density when the radiation is incident normally on the detector surface.
TYPICAL UNITS: V/W, A/W

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Rise Time (t_r)

The time duration during which the leading edge of a pulse is increasing from 10% to 90% of its maximum amplitude.

Spectral Bandwidth (between Half-Power Points) (B)

The wavelength interval in which a photometric or radiometric spectral quantity is not less than half of its maximum value.

Spectral Output (of a Light-Emitting Diode)

A description of the radiant-energy or light-emission characteristic versus wavelength.
NOTE: This information is usually given by stating the wavelength at peak emission and the bandwidth between half-power points or by means of a curve.

Spectral Response (of a Photosensitive Device)

A description of the electrical-output characteristic versus wavelength of radiant energy incident upon the device.
NOTE: This information is usually given by means of a curve.

Steradian (sr)

A unit of solid angular measurement equal to the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius; there are 4π steradians in a complete sphere.

Storage Time (t_s)

The time interval from a point at which the trailing edge of the input pulse has dropped to 90% of its maximum amplitude to a point at which the trailing edge of the output pulse has dropped to 90% of its maximum amplitude.

Visible Emission, Visible Light

Radiation which is characterized by wavelengths of about 0.38 μm to 0.78 μm.

Visible-Light-Emitting Diode (VLED)

An optoelectronic device containing a semiconductor junction which emits visible light when forward-biased. See light-emitting diode for graphic symbol.
NOTE: Material is usually gallium phosphide (GaP) or gallium arsenide phosphide (GaAsP)

Wavelength at Peak Emission (λ_p)

The wavelength at which the power output from a light-emitting diode is maximum.
TYPICAL UNITS: Å, μm, nm.1 Å = 10^{-4} μm = 0.1 nm.

Competitive Cross-Reference Guide

OPTOELECTRONICS

COMPETITIVE CROSS-REFERENCE GUIDE

This competitive cross reference guide has been revised to include almost 500 standard optoelectronic devices and assemblies built by domestic manufacturers.

Please observe that many of the TI part numbers listed are noted with an asterisk(*), which denotes that the TI equivalent is not exactly identical to the competitive device. In all cases where the TI equivalent is not exactly the same, there will be either minor variations in the key electrical parameters or mechanical configuration differences.

Since optoelectronics is a relatively young and varied industry, it is possible that several devices offered by different manufacturers will satisfy the requirements of one application. Therefore, it is important to realize that slight mechanical or electrical variations should not disqualify the nearest equivalent.

The data contained in this guide is believed to be accurate. However, no responsibility is assumed by Texas Instruments Incorporated for the use of this data in actual circuit design.

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
1N2175		Photodiode	1N2175
2N986		Phototransistor	TIL81*
2N2452		Phototransistor	TIL81*
3N-903†	ENL	Optically Coupled Isolator	TIL107*
3N-903-N†	ENL	Optically Coupled Isolator	TIL108*
521-9165	Dialco	Visible Emitter	TIL210*
521-9166	Dialco	Visible Emitter	TIL210*
521-9167	Dialco	Visible Emitter	TIL210*
521-9168	Dialco	Visible Emitter	TIL210*
745-0001	Dialco	Visible Numeric Display	TIL310*
745-0002	Dialco	Visible Numeric Display	TIL310*
745-0003	Dialco	Visible Numeric Display	TIL302
745-0004	Dialco	Visible Numeric Display	TIL303
745-0006	Dialco	Visible ±1 Display	TIL304
749-0306	Dialco	Visible Numeric Display, 6-Digit	TIXL360*
4532	RCA	Silicon Vidicon Image Tube	VID2501*
4532A	RCA	Silicon Vidicon Image Tube	VID2501*
40598	RCA	IR Emitter	TIL23*
40598A	RCA	IR Emitter	TIL24*
40736R	RCA	IR Emitter	TIL24*
CLT2010	Clairex	Phototransistor	TIL81*
CLT2020	Clairex	Phototransistor	TIL81*
CTL2030	Clairex	Phototransistor	TIL81*
CLT2130	Clairex	Phototransistor	TIL81*
CLT2140	Clairex	Phototransistor	TIL81*
CLT2150	Clairex	Phototransistor	TIL81*
CLT2160	Clairex	Phototransistor	TIL81*
CLT3020	Clairex	Phototransistor	TIL605*
CLT3030	Clairex	Phototransistor	TIL606*

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†These are the designations of the indicated manufacturer and should not be confused with JEDEC designations.

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
CLT3160	Clairex	Phototransistor	TIL602*
CLT3170	Clairex	Phototransistor	TIL604*
CLT4020	Clairex	Phototransistor	TIL613*
CLT4030	Clairex	Phototransistor	TIL614*
CLT4160	Clairex	Phototransistor	TIL610*
CLT4170	Clairex	Phototransistor	TIL612*
CM4-1 Red	Chicago Miniature	Visible Emitter	TIL204
CM4-20 Clear	Chicago Miniature	Visible Emitter	TIL210*
CM4-21 Clear	Chicago Miniature	Visible Emitter	TIL210*
CM4-22 Red	Chicago Miniature	Visible Emitter	TIL210*
CM4-23 Red	Chicago Miniature	Visible Emitter	TIL210*
CM4-50 Red	Chicago Miniature	Visible Emitter	TIL209*
CM4-103	Chicago Miniature	Visible Numeric Display	TIL310*
CM4-100	Chicago Miniature	Visible Numeric Display	TIL302
CM4-110	Chicago Miniature	Visible Numeric Display	TIL302*
CM4-101	Chicago Miniature	Visible ±1 Display	TIL304
CM4-111	Chicago Miniature	Visible ±1 Display	TIL304*
CM-710	HEI	Phototransistor Card Reader Array, 10-Element	TIL132* Special
CR-712	HEI	Phototransistor Card Reader Array, 12-Element	TIL135*
DATA-LIT3	Litronix	Visible Numeric Display	TIL302*
DATA-LIT6	Litronix	Visible Numeric Display	TIL302*
DATA-LIT8	Litronix	Visible Numeric Display	TIL302*
DATA-LIT10	Litronix	Visible Numberic Display	TIL302
DATA-LIT10A	Litronix	Visible Numeric Display	TIL302*
DATA-LIT57	Litronix	Visible Alpha-Numeric Display	TIL305
DATA-LIT81	Litronix	Visible ± 1 Display	TIL304*
DATA-LIT101	Litronix	Visible ±1 Display	TIL304
DATA-LIT101A	Litronix	Visible ± 1 Display	TIL304*
DATA-LIT300	Litronix	Visible Numeric Display	TIXL360*
E-401W	ENL	IR Emitter	TIL31*
E-473A	ENL	IR Emitter	TIL31*
E-498	ENL	Visible Emitter	TIL204*
ED123	Sprague	Visible Emitter	TIL210*
ED150	Sprague	Visible Emitter	TIL209*
ED201	Sprague	Visible Numeric Display	TIL302*
ED203	Sprague	Visible Numeric Display	TIL310*
ED360	Sprague	IR Emitter	TIL32*
ED401	Sprague	Phototransistor	TIL81*
ED702	Sprague	Optically Coupled Isolator	TIL111*
EQT-381-XXX	HEI	Source-Detector Assembly, 1-Channel	TIL139*
FLD100	Fairchild	IR Emitter	TIL32*
FLV100	Fairchild	Visible Emitter	TIL209*
FLV101	Fairchild	Visible Emitter	TIL209*
FLV102	Fairchild	Visible Emitter	TIL209*
FLV110	Fairchild	Visible Emitter	TIL209*
FND10	Fairchild	Visible Numeric Display	TIL310*
FND10A	Fairchild	Visible Numeric Display	TIL310*
FND21	Fairchild	Visible Numeric Display	TIXL360*
FPA210	Fairchild	Source-Detector Assembly	TIXL138*

COMPETITIVE CROSS-REFERENCE GUIDE

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
FPA700	Fiarchild	Phototransistor Tape Reader Array, 9-Element	TIL132*
FPA700A	Fairchild	Phototransistor Tape Reader Array, 9-Element	TIL132*
FPA710	Fairchild	Phototransistor Card Reader Array, 12-Element	TIL135*
FPA710A	Fairchild	Phototransistor Card Reader Array, 12-Element	TIL135*
FPA720	Fairchild	Phototransistor Card Reader Array, 10-Element	TIL135* Special
FPA720A	Fairchild	Phototransistor Card Reader Array-10 Element	TIL135* Special
FPF110	Fairchild	Phototransistor	TIL63*
FPF110A	Fairchild	Phototransistor	TIL66*
FPF110B	Fairchild	Phototransistor	TIL66*
FPF130	Fairchild	Phototransistor	TIL67*
FPF130A	Fairchild	Phototransistor	TIL67*
FPF130B	Fairchild	Phototransistor	TIL67*
FPLA700	Fairchild	Phototransistor/IR Emitter Tape Reader Assembly, 9-Channel	TIL133*
FPLA710	Fairchild	Phototransistor/IR Emitter Card Reader Assembly, 12-Channel	TIL136*
FPLA720	Fairchild	Phototransistor/IR Emitter Card Reader Assembly, 10-Channel	TIL136* Special
FPLA810	Fairchild	Optically Coupled Isolator	TIL112*
FPLA820	Fairchild	Optically Coupled Isolator	TIL111
FPLA850	Fairchild	Source-Detector Assembly, 1-Channel	TIL139*
FPLA850A	Fairchild	Source-Detector Assembly, 1-Channel	TIL139*
FPM100	Fairchild	Phototransistor	TIL613*
FPM200	Fairchild	Photodiode	TIL613*
FPO100	Fairchild	Phototransistor	TIL613*
FPO200	Fairchild	Photodiode	TIL613*
FPT100	Fairchild	Phototransistor	TIL63*
FPT100A	Fairchild	Phototransistor	TIL67*
FPT100B	Fairchild	Phototransistor	TIL67*
FPT120	Fairchild	Phototransistor	TIL78*
FPT120A	Fairchild	Phototransistor	TIL67*
FPT120B	Fairchild	Phototransistor	TIL67*
GS-100	General Sensor	Phototransistor	TIL606
GS-300	General Sensor	Phototransistor	TIL58
GS-400	General Sensor	Phototransistor	LS400
GS-420	General Sensor	Phototransistor	LS400
GS-600	General Sensor	Phototransistor	TIL81*
GS-610	General Sensor	Phototransistor	TIL81*
HLS400	Hutson	Phototransistor	LS400
HP5082-4104	Hewlett Packard	IR Emitter	TIL31*
HP5082-4107	Hewlett Packard	IR Emitter	TIL23*
HP5082-4120	Hewlett Packard	IR Emitter	TIL31*
HP5082-4201	Hewlett Packard	Photodiode	TIXL80*
HP5082-4203	Hewlett Packard	Photodiode	TIXL80*
HP5082-4204	Hewlett Packard	Photodiode	TIXL80*
HP5082-4205	Hewlett Packard	Photodiode	TIXL80*
HP5082-4207	Hewlett Packard	Photodiode	TIXL80*
HP5082-4220	Hewlett Packard	Photodiode	TIXL80*
HP5082-4301	Hewlett Packard	Optically Coupled Isolator	TIXL109*
HP5082-4303	Hewlett Packard	Optically Coupled Isolator	TIXL109*
HP5082-4309	Hewlett Packard	Optically Coupled Isolator	TIXL109*
HP5082-4310	Hewlett Packard	Optically Coupled Isolator	TIL107*

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
HP5082-4317	Hewlett Packard	Optically Coupled Isolator	TIL102*
HP5082-4320	Hewlett Packard	Optically Coupled Isolator	TIL107*
HP5082-4400	Hewlett Packard	Visible Emitter	TIL204*
HP5082-4403	Hewlett Packard	Visible Emitter	TIL210*
HP5082-4405	Hewlett Packard	Visible Emitter	TIL203*
HP5082-4410	Hewlett Packard	Visible Emitter	TIL210*
HP5082-4415	Hewlett Packard	Visible Emitter	TIL210
HP5082-4417	Hewlett Packard	Visible Emitter	TIL210*
HP5082-4420	Hewlett Packard	Visible Emitter	TIL204*
HP5082-4440	Hewlett Packard	Visible Emitter	TIL210
HP5082-4444	Hewlett Packard	Visible Emitter	TIL210
HP5082-7000	Hewlett Packard	Visible Numeric Display With Logic	TIL306*
HP5082-7001	Hewlett Packard	Visible Numeric Display With Logic, 3-Digit	TIL306*(3 req'd)
HP5082-7018	Hewlett Packard	Visible ± 1 Display	TIL304* With Separate Logic
HP5082-7100	Hewlett Packard	Visible Alpha-Numeric Display, 3-Character	TIL305*
HP5082-7101	Hewlett Packard	Visible Alpha-Numeric Display, 4-Character	TIL305*
HP5082-7102	Hewlett Packard	Visible Alpha-Numeric Display, 5-Character	TIL305*
HP5082-7210	Hewlett Packard	Visible Numeric Display, 3-Digit	TIXL360*
HP5082-7211	Hewlett Packard	Visible Numeric Display, 4-Digit	TIXL360*
HP5082-7212	Hewlett Packard	Visible Numeric Display, 5-Digit	TIXL360*
HP5082-7215	Hewlett Packard	Visible Numeric Display, 3-Digit	TIXL360*
HP5082-7216	Hewlett Packard	Visible Numeric Display, 4-Digit	TIXL360*
HP5082-7217	Hewlett Packard	Visible Numeric Display, 5-Digit	TIXL360*
HP5082-7300	Hewlett Packard	Visible Numeric Display With Logic	TIL306* With Separate Logic
HP5082-7302	Hewlett Packard	Visible Numeric Display With Logic	TIL306*
HP5082-7304	Hewlett Packard	Visible ± 1 Display With Logic	TIL304* With Separate Logic
HT-700	HEI	Phototransistor	TIL78*
IR-LIT40	Litronix	IR Emitter	TIXL26*
IR-LIT60	Litronix	IR Emitter	TIL32*
ISO-LIT1	Litronix	Optically Coupled Isolator	TIL111*
ISO-LIT12	Litronix	Optically Coupled Isolator	TIL112
ISO-LIT16	Litronix	Optically Coupled Isolator	TIL112*
L14B	GE	Photodarlington	LS869‡
LA-09	HEI	Phototransistor Tape Reader Array, 9-Element	TIL132*
LA-600	HEI	Phototransistor	TIL601*
LA-700	HEI	Phototransistor	TIL63*
LA-609-X-X	HEI	Phototransistor Tape Reader Array, 9-Element	TIL132*
LD100	Sylvania	Visible Emitter	TIL203*
LE103	GE	Avalanche Photodiode Module	TIXL74*
LEA-400	HEI	IR Emitter	TIL23*
LEA-409-X-X	HEI	IR Emitter Tape Reader Array, 9-Element	TIL131*
LEA-500	HEI	IR Emitter	TIL23*
MAN1	Monsanto	Visible Numeric Display	TIL302
MAN1A	Monsanto	Visible Numeric Display	TIL302*
MAN1B	Monsanto	Visible Numeric Display	TIL302*
MAN1BA	Monsanto	Visible Numeric Display	TIL302*
MAN2	Monsanto	Visible Alpha-Numeric Display	TIL305

‡This product is presently under development. A standard device designation will be announced at a later date.

COMPETITIVE CROSS-REFERENCE GUIDE

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
MAN2A	Monsanto	Visible Alpha-Numeric Display	TIL305
MAN3	Monsanto	Visible Numeric Display	TIL310*
MAN3A	Monsanto	Visible Numeric Display	TIL310*
MAN4	Monsanto	Visible Numeric Display	TIL302*
MAN1001	Monsanto	Visible ±1 Display	TIL304
MAN1001A	Monsanto	Visible ±1 Display	TIL304*
MAN1002	Monsanto	Visible Numeric Display	TIXL311*
MAN1002A	Monsanto	Visible Numeric Display	TIXL311*
MCA2-30	Monsanto	Optically Coupled Isolator	TIXL113*
MCA2-55	Monsanto	Optically Coupled Isolator	TIXL113*
MCD1	Monsanto	Optically Coupled Isolator	TIL111
MCD2	Monsanto	Optically Coupled Isolator	TIL111*
MCD4	Monsanto	Optically Coupled Isolator	TIL102*
MCT1	Monsanto	Optically Coupled Isolator	TIL107*
MCT2	Monsanto	Optically Coupled Isolator	TIL111*
MCT2E	Monsanto	Optically Coupled Isolator	TIL111*
MCT4	Monsanto	Optically Coupled Isolator	TIL102*
MCT5-10	Monsanto	Optically Coupled Isolator	TIXL109* Special
MCT26	Monsanto	Optically Coupled Isolator	TIL112*
MDA6101	Monsanto	Visible Numeric Display With Logic	TIL308*
ME1	Monsanto	IR Emitter	TIL24*
ME2	Monsanto	IR Emitter	TIXL27*
ME2A	Monsanto	IR Emitter	TIXL27*
ME3	Monsanto	IR Emitter	TIL23*
ME4	Monsanto	IR Emitter	TIXL26*
ME5	Monsanto	IR Emitter	TIXL27
ME5A	Monsanto	IR Emitter	TIXL27
ME6	Monsanto	IR Emitter	TIL23*
ME7	Monsanto	IR Emitter	TIL23*
ME60	Monsanto	IR Emitter	TIL32*
MI20C	Monsanto	IR Emitter	TIXL26*
MLED50	Motorola	Visible Emitter	TIL209*
MLED60	Motorola	IR Emitter	TIL32*
MLED90	Motorola	IR Emitter	TIL32*
MLED600	Motorola	Visible Emitter	TIL209*
MLED610	Motorola	Visible Emitter	TIL206*
MLED630	Motorola	Visible Emitter	TIL203*
MLED900	Motorola	IR Emitter	TIL32*
MLED910	Motorola	IR Emitter	TIL23
MLED930	Motorola	IR Emitter	TIL31*
MOC1000	Motorola	Optically Coupled Isolator	TIL111*
MOR33	Motorola	Visible Numeric Display	TIL310*
MPC1	Monsanto	Visible Numeric Display	TIL310*
MPC2	Monsanto	Visible Numeric Display	TIXL360*
MPC3	Monsanto	Visible Numeric Display	TIXL360*
MRD100	Motorola	Phototransistor	TIL78*
MRD150	Motorola	Phototransistor	TIL78*
MRD200	Motorola	Photodiode	TIL603*
MRD210	Motorola	Photodiode	TIL601*

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
MRD250	Motorola	Photodiode	TIL602*
MRD300	Motorola	Phototransistor	TIL81*
MRD310	Motorola	Phototransistor	TIL81*
MRD450	Motorola	Phototransistor	TIL78*
MRD500	Motorola	Pin Photodiode	LSX900*
MRD510	Motorola	Pin Photodiode	LSX900*
MRD600	Motorola	Phototransistor	TIL601*
MRD810	Motorola	Phototransistor	TIL81*
MRD3050	Motorola	Phototransistor	TIL81*
MRD3051	Motorola	Phototransistor	TIL81*
MRD3052	Motorola	Phototransistor	TIL81*
MRD3053	Motorola	Phototransistor	TIL81*
MRD3054	Motorola	Phototransistor	TIL81*
MRD3055	Motorola	Phototransistor	TIL81*
MRD3056	Motorola	Phototransistor	TIL81*
MT1	Monsanto	Phototransistor	TIL81*
MT2	Monsanto	Phototransistor	TIL81*
MV2	Monsanto	Visible Emitter	SL1181‡
MV3	Monsanto	Visible Emitter	TIL203*
MV5	Monsanto	Visible Emitter	TIL205*
MV10A	Monsanto	Visible Emitter	TIL205
MC10A3	Monsanto	Visible Emitter	TIL205
MV10B	Monsanto	Visible Emitter	TIL203
MV10B3	Monsanto	Visible Emitter	TIL203
MV10C	Monsanto	Visible Emitter	TIL204*
MV50	Monsanto	Visible Emitter	TIL209*
MV50A	Monsanto	Visible Emitter	TIL209*
MV5010	Monsanto	Visible Emitter	TIL210*
MV5011	Monsanto	Visible Emitter	TIL210*
MV5012	Monsanto	Visible Emitter	TIL210*
MV5013	Monsanto	Visible Emitter	TIL210*
MV5020	Monsanto	Visible Emitter	TIL210*
MV5021	Monsanto	Visible Emitter	TIL210*
MV5022	Monsanto	Visible Emitter	TIL210*
MV5023	Monsanto	Visible Emitter	TIL210
MV5024	Monsanto	Visible Emitter	TIL210
MV5025	Monsanto	Visible Emitter	TIL210*
MV5030	Monsanto	Visible Emitter	TIL210*
MV5033	Monsanto	Visible Emitter	TIL210*
MV5080	Monsanto	Visible Emitter	TIL209*
MV5082	Monsanto	Visible Emitter	TIL209*
NSL610	National	Phototransistor	TIL81*
OP100	Optron	IR Emitter	TIL23
OP122	Optron	IR Emitter	TIL23
OP123	Optron	IR Emitter	TIL23
OP400	Optron	Phototransistor	LS400
OP420	Optron	Phototransistor	LS400
OP490	Optron	Photodiode	LSX900*
OP563	Optron	Phototransistor	TIL63

‡This product is presently under development. A standard device designation will be announced at a later date.

COMPETITIVE CROSS-REFERENCE GUIDE

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
OP564	Optron	Phototransistor	TIL64
OP565	Optron	Phototransistor	TIL65
OP566	Optron	Phototransistor	TIL66
OP567	Optron	Phototransistor	TIL67
OP568	Optron	Phototransistor	TIL63
OP569	Optron	Phototransistor	TIL64
OP570	Optron	Phototransistor	TIL65
OP571	Optron	Phototransistor	TIL66
OP572	Optron	Phototransistor	TIL67
OP600	Optron	Phototransistor	LS600
OP601	Optron	Phototransistor	TIL601
OP602	Optron	Phototransistor	TIL602
OP603	Optron	Phototransistor	TIL603
OP604	Optron	Phototransistor	TIL604
OP605	Optron	Phototransistor	TIL604*
OP606	Optron	Phototransistor	TIL603
OP607	Optron	Phototransistor	TIL601
OP608	Optron	Phototransistor	TIL602
OP611	Optron	Phototransistor	TIL601
OP612	Optron	Phototransistor	TIL602
OP613	Optron	Phototransistor	TIL603
OP614	Optron	Phototransistor	TIL604
OP620	Optron	Phototransistor	TIL601
OP621	Optron	Phototransistor	TIL601
OP622	Optron	Phototransistor	TIL602
OP623	Optron	Phototransistor	TIL603
OP624	Optron	Phototransistor	TIL604
OP630	Optron	Phototransistor	LS600*
OP631	Optron	Phototransistor	LS600*
OP632	Optron	Phototransistor	LS600*
OP633	Optron	Phototransistor	LS600*
OP634	Optron	Phototransistor	LS600*
OP700	Optron	Phototransistor	TIL612
OP790	Optron	Photodiode	LSX900*
OP900	Optron	Photodiode	LSX900*
OP1020	Optron	Optically Coupled Isolator	TIXL109*
OP1022	Optron	Optically Coupled Isolator	TIL111*
OP1023	Optron	Optically Coupled Isolator	TIXL109*
OP1025	Optron	Optically Coupled Isolator	TIXL109*
OP1030	Optron	Optically Coupled Isolator	TIXL109*
OP1032	Optron	Optically Coupled Isolator	TIL112*
OP1033	Optron	Optically Coupled Isolator	TIXL109*
OP1035	Optron	Optically Coupled Isolator	TIXL109*
OP1060	Optron	Optically Coupled Isolator	TIXL109*
OP1062	Optron	Optically Coupled Isolator	TIL112*
OP1063	Optron	Optically Coupled Isolator	TIXL109*
OP1065	Optron	Optically Coupled Isolator	TIXL109*
OP1090	Optron	Optically Coupled Isolator	TIXL109*
OPA508	Optron	Phototransistor Tape Reader Array, 9-Element	TIL132*

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
OPA508A	Optron	Phototransistor Tape Reader Array, 9-Element	TIL132*
OPA512	Optron	Phototransistor Card Reader Array, 12-Element	TIL135*
OPA512A	Optron	Phototransistor Card Reader Array, 12-Element	TIL135*
OPB120	Optron	Source-Detector Assembly, 1-Channel	TIL138*
OPB125	Optron	Source-Detector Assembly, 1-Channel	TIL139*
OPE508	Optron	IR Emitter Tape Reader Array, 9-Element	TIL131*
OPE512	Optron	IR Emitter Card Reader Array, 12-Element	TIL134*
OS-581	HEI	Source-Detector Assembly, 1-Channel	TIL138*
OSL-1	OPCOA	Visible Emitter	TIL206*
OSL-2	OPCOA	Visible Emitter	TIL206*
OSL-3	OPCOA	Visible Emitter	TIL204*
OSL-4	OPCOA	Visible Emitter	TIL206*
PC4-73	GE	Optically Coupled Isolator	TIL103*
PC15-26	GE	Optically Coupled Isolator	TIL108*
PT-904L	ENL	Phototransistor	TIL65*
QS-100	Quantum Sensing	Phototransistor	TIL63*
QS-101	Quantum Sensing	Phototransistor	TIL64*
QS-102	Quantum Sensing	Phototransistor	TIL65*
QS-103	Quantum Sensing	Phototransistor	TIL66*
QS-104	Quantum Sensing	Phototransistor	TIL67*
QS-105	Quantum Sensing	Phototransistor	TIL64*
QS-106	Quantum Sensing	Phototransistor	TIL67*
QS-107	Quantum Sensing	Phototransistor	TIL65*
QS-200	Quantum Sensing	Phototransistor	TIL614*
QS-201	Quantum Sensing	Phototransistor	TIL615*
QS-202	Quantum Sensing	Phototransistor	TIL613*
QS-203	Quantum Sensing	Phototransistor	TIL615*
QS-204	Quantum Sensing	Phototransistor	TIL614
QS-205	Quantum Sensing	Phototransistor	TIL615
QS-230	Quantum Sensing	Phototransistor	TIL614
QS-400	Quantum Sensing	Phototransistor	LS400
QS-401	Quantum Sensing	Phototransistor	LS400*
QS-402	Quantum Sensing	Phototransistor	LS400*
QS-403	Quantum Sensing	Phototransistor	LS400*
QS-404	Quantum Sensing	Phototransistor	LS400*
QS-600	Quantum Sensing	Phototransistor	LS600
QS-601	Quantum Sensing	Phototransistor	TIL601
QS-602	Quantum Sensing	Phototransistor	TIL602
QS-603	Quantum Sensing	Phototransistor	TIL603
QS-604	Quantum Sensing	Phototransistor	TIL604
QS-605	Quantum Sensing	Phototransistor	TIL604*
QS-3600	Quantum Sensing	Phototransistor Tape Reader Array, 9-Element	TIL132*
QS-8014	Quantum Sensing	Phototransistor Card Reader Assembly, 12-Element	TIL135*
QSL-1	Quantum Sensing	Photodiode	1N2175
QSL-11	Quantum Sensing	Photodiode	H11
QSL-35	Quantum Sensing	Photodiode	H35
QSL-38	Quantum Sensing	Photodiode	H38
QSL-60	Quantum Sensing	Photodiode	H60
QSL-61	Quantum Sensing	Photodiode	H61

COMPETITIVE CROSS-REFERENCE GUIDE

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
QSL-62	Quantum Sensing	Photodiode	H62
R7M-192-X	Bowmar	Visible Numeric Display	TIXL360*
RED-LIT2	Litronix	Visible Emitter	TIL210*
RED-LIT4	Litronix	Visible Emitter	TIL203*
RED-LIT7	Litronix	Visible Emitter	TIL204*
RED-LIT50	Litronix	Visible Emitter	TIL209*
S10XQA, Level A	Amperex	Silicon Vidicon Image Tube	VID2501*
S10XQA, Level B	Amperex	Silicon Vidicon Image Tube	VID2501*
S10XQA, Level C	Amperex	Silicon Vidicon Image Tube	VID2502*
SC-1481-1	Spectronics	Optically Coupled Isolator	TIXL113*
SC-1481-2	Spectronics	Optically Coupled Isolator	TIXL113*
SC-1481-3	Spectronics	Optically Coupled Isolator	TIXL113*
SC-1482-1	Spectronics	Optically Coupled Isolator	TIL111*
SC-1482-2	Spectronics	Optically Coupled Isolator	TIL111*
SC-1482-3	Spectronics	Optically Coupled Isolator	TIL111*
SC-1484-1	Spectronics	Optically Coupled Isolator	TIL107*
SC-1484-2	Spectronics	Optically Coupled Isolator	TIL108*
SC-1484-3	Spectronics	Optically Coupled Isolator	TIL108*
SD-1420-1	Spectronics	Photodiode	LSX900*
SD-1420-2	Spectronics	Photodiode	LSX900*
SD-1440-1	Spectronics	Phototransistor	TIL610*
SD-1440-2	Spectronics	Phototransistor	TIL611*
SD-1440-3	Spectronics	Phototransistor	TIL612*
SD-1440-4	Spectronics	Phototransistor	TIL612*
SD-1441-1	Spectronics	Phototransistor	TIL609*
SD-1441-2	Spectronics	Phototransistor	TIL610*
SD-1441-3	Spectronics	Phototransistor	TIL611*
SD-2420-1	Spectronics	Photodiode	LSX900*
SD-2420-2	Spectronics	Photodiode	LSX900*
SD-2440-1	Spectronics	Phototransistor	TIL601
SD-2440-2	Spectronics	Phototransistor	TIL602
SD-2440-3	Spectronics	Phototransistor	TIL603
SD-2440-4	Spectronics	Phototransistor	TIL604
SD-2441-1	Spectronics	Phototransistor	TIL603*
SD-2441-2	Spectronics	Phototransistor	TIL604*
SD-2441-3	Spectronics	Phototransistor	TIL604*
SD-3420-1	Spectronics	Photodiode	TIL81*
SD-3420-2	Spectronics	Photodiode	TIL81*
SD-3440-1	Spectronics	Phototransistor	TIL81*
SD-3440-2	Spectronics	Phototransistor	TIL81*
SD-3440-3	Spectronics	Phototransistor	TIL81*
SD-3442-1	Spectronics	Phototransistor	TIL81*
SD-3442-2	Spectronics	Phototransistor	TIL81*
SD-3442-3	Spectronics	Phototransistor	TIL81*
SD-5420-1	Spectronics	Photodiode	TIL81*
SD-5420-2	Spectronics	Photodiode	TIL81*
SD-5421-1	Spectronics	Photodiode	TIL81*
SD-5421-2	Spectronics	Photodiode	TIL81*
SD-5440-1	Spectronics	Phototransistor	TIL81*

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
SD-5440-2	Spectronics	Phototransistor	TIL81*
SD-5440-3	Spectronics	Phototransistor	TIL81*
SD-5440-4	Spectronics	Phototranssitor	TIL81*
SD-5442-1	Spectronics	Phototransistor	TIL81*
SD-5442-2	Spectronics	Phototransistor	TIL81*
SD-5442-3	Spectronics	Phototransistor	TIL81*
SE-1450-1	Spectronics	IR Emitter	TIL23*
SE-1450-2	Spectronics	IR Emitter	TIL23*
SE-1450-3	Spectronics	IR Emitter	TIL23*
SE-1450-4	Spectronics	IR Emitter	TIL24*
SE-2430-1	Spectronics	IR Emitter	TIL31*
SE-2430-2	Spectronics	IR Emitter	TIL31*
SE-2430-3	Spectronics	IR Emitter	TIL31*
SE-2430-4	Spectronics	IR Emitter	TIL31*
SE-2450-1	Spectronics	IR Emitter	TIL23
SE-2450-2	Spectronics	IR Emitter	TIL23
SE-2450-3	Spectronics	IR Emitter	TIL23
SE-2460-1	Spectronics	IR Emitter	TIL23
SE-2460-2	Spectronics	IR Emitter	TIL23
SE-2460-3	Spectronics	IR Emitter	TIL24
SE-2460-4	Spectronics	IR Emitter	TIL24
SE-3450-1	Spectronics	IR Emitter	TIL31*
SE-3450-2	Spectronics	IR Emitter	TIL31*
SE-3450-3	Spectronics	IR Emitter	TIL31*
SE-5450-1	Spectronics	IR Emitter	TIL31
SE-5450-2	Spectronics	IR Emitter	TIL31
SE-5450-3	Spectronics	IR Emitter	TIL31
SE-5451-1	Spectronics	IR Emitter	TIL31
SE-5451-2	Spectronics	IR Emitter	TIL31
SE-5451-3	Spectronics	IR Emitter	TIL31
SE-6474-020	Spectronics	IR Emitter	TIXL13
SE-6474-030	Spectronics	IR Emitter	TIXL12
SE-6474-040	Spectronics	IR Emitter	TIXL12
SE-6477-030	Spectronics	IR Emitter	TIXL15
SE-6477-040	Spectronics	IR Emitter	TIXL14
SE-6477-060	Spectronics	IR Emitter	TIXL14
SE-6478-2	Spectronics	IR Emitter	TIXL16*
SGD-100A	EG&G	Photodiode	TIXL80*
SLA-1	OPCOA	Visible Numeric Display	TIL302*
SSL-3	GE	IR Emitter	TIL31*
SSL-3F	GE	IR Emitter	TIL31*
SSL-4	GE	IR Emitter	TIL31*
SSL-5A	GE	IR Emitter	TIL31*
SSL-5B	GE	IR Emitter	TIL31*
SSL-5C	GE	IR Emitter	TIL31*
SSL-12	GE	Visible Emitter	TIL209*
SSL-15	GE	IR Emitter	TIL24*
SSL-22	GE	Visible Emitter	TIL210*
SSL-22L	GE	Visible Emitter	TIL210*

COMPETITIVE CROSS-REFERENCE GUIDE

COMPETITIVE PART NUMBER	MANUFACTURER	DEVICE TYPE	TI EQUIVALENT
SSL-34	GE	IR Emitter	TIL31*
SSL-35	GE	IR Emitter	TIL31*
SSL-54	GE	IR Emitter	TIL31*
SSL-55B	GE	IR Emitter	TIL31*
SSL-55C	GE	IR Emitter	TIL31*
SSL-140	GE	Visible Numeric Display	TIL310*
SSL-190	GE	Visible Numeric Display	TIL302*
SSL-212	GE	Visible Emitter	TIL209*
SSL-315	GE	IR Emitter	TIL24*
ST/A71	Sensor Technology	Phototransistor Tape Reader Array, 9-Element	TIL132*
ST/A72	Sensor Technology	Phototransistor Tape Reader Array, 9-Element	TIL132*
STPT40	Sensor Technology	Phototransistor	LS400
STPT60	Sensor Technology	Phototransistor	LS600
STPT300	Sensor Technology	Phototransistor	TIL81*
STPT310	Sensor Technology	Phototransistor	TIL81*
TA7437R	RCA	IR Emitter	TIL24*
TA7762R	RCA	IR Emitter	TIL24*
UDT-400	United Detector Technology	Photodiode	TIXL80*
UDT-600	United Detector Technology	Photodiode	TIXL80*
YAG-100	EG&G	Photodiode	TIXL80
Z-7975	GE	Silicon Vidicon Image Tube	VID2501*

Light Sensors

QUICK REFERENCE GUIDE
LIGHT SENSORS

LIGHT SENSORS
QUICK REFERENCE GUIDE

DEVICE	TYPE	PKG	LIGHT CURRENT			DARK CURRENT		POWER	FEATURES
			MIN	MAX	@ V	MAX	@ V	DISS.	
1N2175	Photodiode	3 Z	100 µA		±10	0.5 µA	±50	50 mW	Glass, hermetically sealed
1N5722	Phototransistor	4 J	0.5 mA	3 mA	5	25 nA	30	50 mW	EIA-Registered versions of TIL601–TIL604
1N5723	Phototransistor	4 J	2 mA	5 mA	5	25 nA	30	50 mW	
1N5724	Phototransistor	4 J	4 mA	8 mA	5	25 nA	30	50 mW	
1N5725	Phototransistor	4 J	7 mA		5	25 nA	30	50 mW	
H11	Photodiode	3 Z	40 µA		±10	0.5 µA	±50	50 mW	Selected versions of 1N2175; can be used with ac bias
H35	Photodiode	3 Z	60 µA		±10	0.5 µA	±50	50 mW	
H38	Photodiode	3 Z	100 µA		±10	10 µA	±50	50 mW	
H60	Photodiode	3 Z	100 µA	200 µA	±10	0.5 µA	±50	50 mW	
H61	Photodiode	3 Z	200 µA	300 µA	±10	0.5 µA	±50	50 mW	
H62	Photodiode	3 Z	300 µA	400 µA	±10	0.5 µA	±50	50 mW	
LS400[†]	Phototransistor	4 B	1 mA		5	25 nA	30	50 mW	Hermetic glass package
LS600[†]	Phototransistor	4 J	0.8 mA		5	25 nA	30	50 mW	Pill package
LSX900	Photodiode	4 A	6 µA		30	9 nA	50	50 mW	GHz demodulator
TIL58	Phototransistor	3 X	1 mA		5	25 nA	30	50 mW	Flat lens LS400
TIL63	Phototransistor	5 S	0.4 mA		5	25 nA	30	50 mW	Low-cost header with epoxy lens. Operating temp. range –40°C to 80°C
TIL64	Phototransistor	5 S	0.4 mA	1.6 mA	5	25 nA	30	50 mW	
TIL65	Phototransistor	5 S	1 mA	4 mA	5	25 nA	30	50 mW	
TIL66	Phototransistor	5 S	2.5 mA	10 mA	5	25 nA	30	50 mW	
TIL67	Phototransistor	5 S	6 mA		5	25 nA	30	50 mW	
TIL77	Photodiode	5 L	1.5 µA		3	5 nA	3		Spectral response similar to human eye
TIL78	Phototransistor	5 J	1 mA		5	25 nA	30	50 mW	Low-cost plastic package
TIL81	As Phototransistor	4 D	5 mA		5	100 nA	10	250 mW	TO-18 package with narrow field of view
	As Photodiode		170 µA Typ		5	10 nA	30	250 mW	
TIL601	Phototransistor	4 J	0.5 mA	3 mA	5	25 nA	30	50 mW	Pill package designed for mounting on double-sided printed board.
TIL602	Phototransistor	4 J	2 mA	5 mA	5	25 nA	30	50 mW	
TIL603	Phototransistor	4 J	5 mA	8 mA	5	25 nA	30	50 mW	
TIL604	Phototransistor	4 J	7 mA		5	25 nA	30	50 mW	
TIL605	Phototransistor	4 K	0.5 mA	3 mA	5	25 nA	30	50 mW	Same as TIL601–TIL604 except wider field of view
TIL606	Phototransistor	4 K	2 mA	5 mA	5	25 nA	30	50 mW	
TIL607	Phototransistor	4 K	4 mA	8 mA	5	25 nA	30	50 mW	
TIL608	Phototransistor	4 K	7 mA		5	25 nA	30	50 mW	
TIL609	Phototransistor	4 L	0.5 mA	3 mA	5	25 nA	30	50 mW	Coaxial package designed for mounting on single-sided printed circuit board
TIL610	Phototransistor	4 L	2 mA	5 mA	5	25 nA	30	50 mW	
TIL611	Phototransistor	4 L	4 mA	8 mA	5	25 nA	30	50 mW	
TIL612	Phototransistor	4 L	7 mA		5	25 nA	30	50 mW	
TIL613	Phototransistor	4 M	0.5 mA	3 mA	5	25 nA	30	50 mW	Same as TIL609–TIL612 except wider field of view
TIL614	Phototransistor	4 M	2 mA	5 mA	5	25 nA	30	50 mW	
TIL615	Phototransistor	4 M	4 mA	8 mA	5	25 nA	30	50 mW	
TIL616	Phototransistor	4 M	7 mA		5	25 nA	30	50 mW	
TIXL51	Photodiode	4 H	60 µA		5	70 nA	30	100 mW	0.1-inch-diameter active area
TIXL52	Photodiode	4 H	15 µA		5	50 nA	30	100 mW	0.05-inch-diameter active area
TIXL53	Photodiode	4 H	6 µA		5	30 nA	30	100 mW	0.03-inch-diameter active area

[†] Special devices available upon request.

TYPE 1N2175
N-P-N DIFFUSED SILICON PHOTO-DUO-DIODE

TYPE 1N2175
BULLETIN NO. DL-S 703313, DECEMBER 1962
REVISED OCTOBER 1970

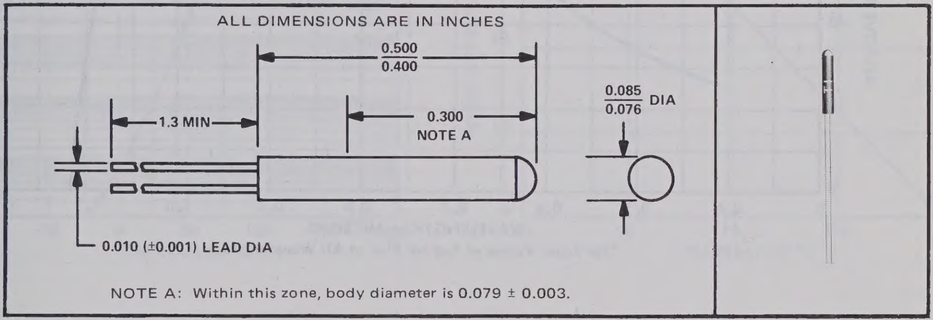
FOR APPLICATION IN:

Tape readout
Card readout
Light switching
Measurement indicators

50 Volts
Designed for 125°C operation
Unlimited altitude range

mechanical data

Hermetically sealed case. Unit weight 0.16 gram.



NOTE A: Within this zone, body diameter is 0.079 ± 0.003.

ratings

conditions	min	typical	max	unit
Bias Voltage @25°C			±50	v
Power Dissipation @25°C			50	mw
Operating Temperature	—65		125	°C
Storage Temperature	—65		125	°C

specifications

conditions	min	typical	max	unit
‡Dark Current @25°C @±50 v		0.01	0.5	μa
Dark Current @100°C @±50 v		20	100	μa
†Light Current @25°C @±10 v	100	200		μa
*Typical Photocurrent Rise Time		2		μs
Typical Photocurrent Fall Time		45		μs
Typical Sensitivity		22.3		μa/mw•cm^2

NOTES:

‡ Dark current is reverse current through the diode with no incident irradiation.

† Light current is measured with irradiance = 9 mw/cm^2 at a wavelength of 0.7 to 1.0 μm determined by a Corning CS 7-69 filter. A two-hour light soak at an illumination of 40 to 80 lm/ft^2 is used prior to measurement of light current to approximate actual operating conditions and improve correlation.

* Rise time is the time required for the photocurrent ** to rise from 10% to 90% of its final value after instantaneous application of excitation. Fall time is the time for the photocurrent to decay from 90% to 10% of its initial value after instantaneous removal of excitation.

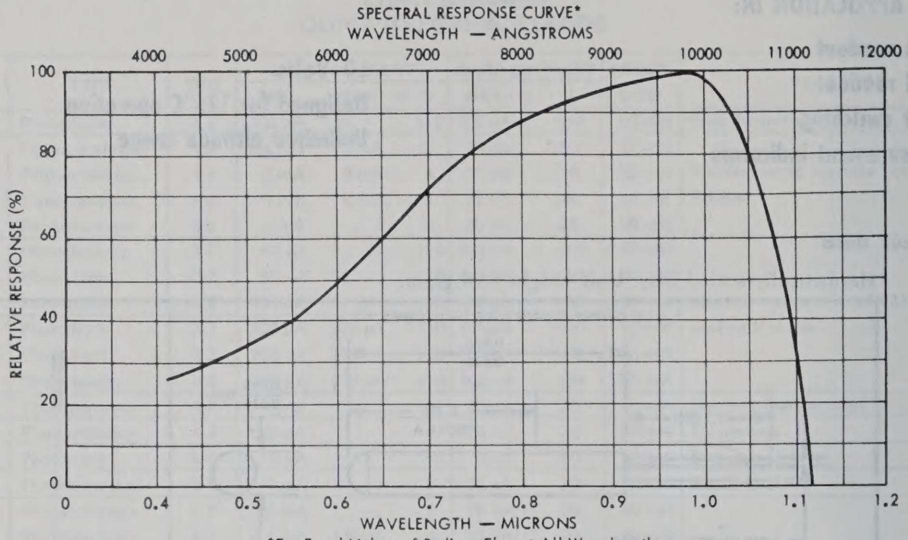
**Photocurrent is the difference between Light Current and Dark Current.

APPLICATION NOTES:

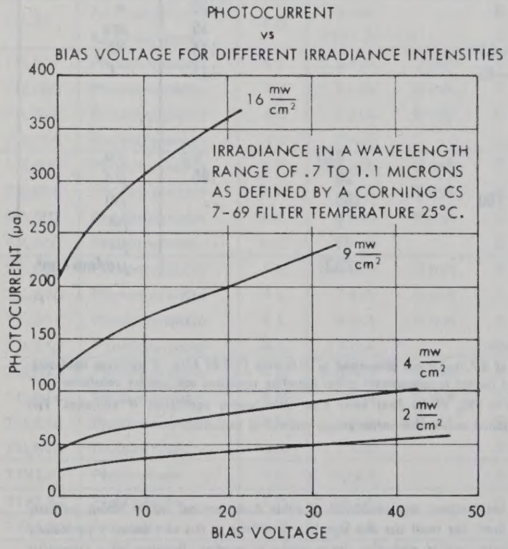
The 1N2175 is a subminiature symmetrically diffused silicon unit. The two junctions are symmetrical so either diode terminal can be biased positively or negatively. Because of this unique design, AC or DC bias voltage can be used. The small size and high light sensitivity of this unit makes it particularly useful in high speed reading of punched cards and tapes, light detection systems, and in production line screening or counting. Numerous other commercial and military applications exist.

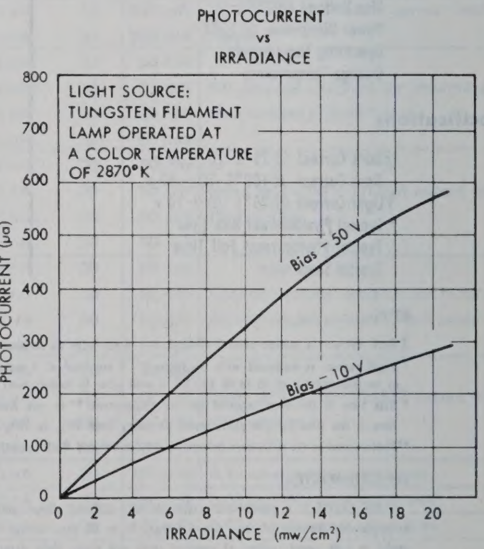
TYPE 1N2175
N-P-N DIFFUSED SILICON PHOTO-DUO-DIODE

TYPICAL CHARACTERISTICS


SPECTRAL RESPONSE CURVE*

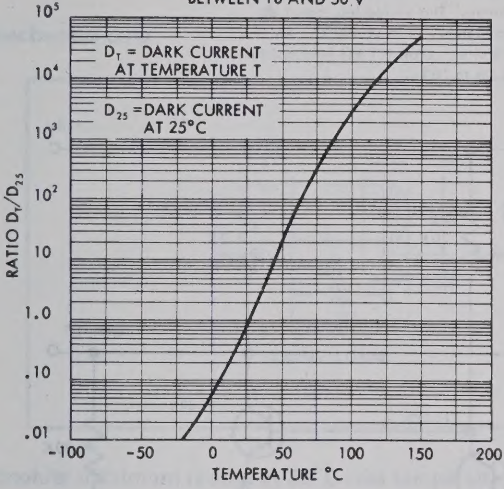
*For Equal Values of Radiant Flux at All Wavelengths


PHOTOCURRENT vs BIAS VOLTAGE FOR DIFFERENT IRRADIANCE INTENSITIES

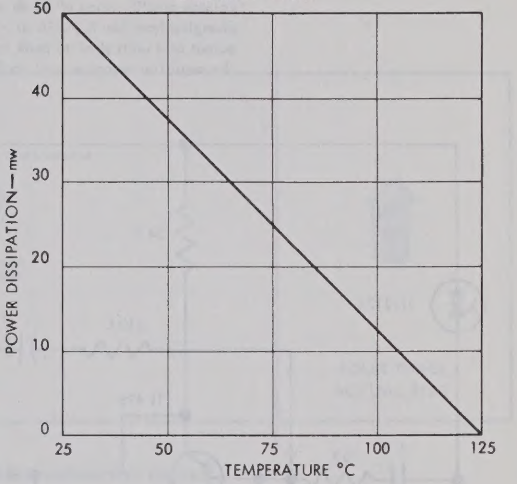

PHOTOCURRENT vs IRRADIANCE

TYPICAL CHARACTERISTICS

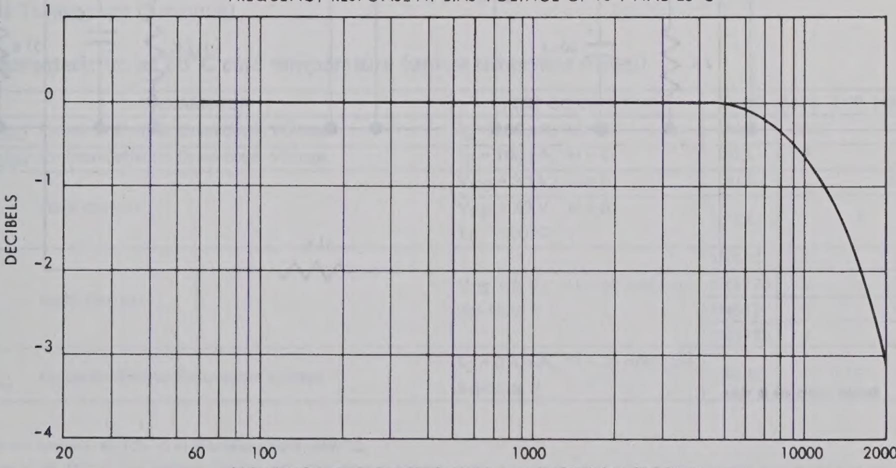
TYPICAL DARK CURRENT CHARACTERISTIC
vs TEMPERATURE
FOR ANY CONSTANT VOLTAGE
BETWEEN 10 AND 50 V



DERATING CURVE



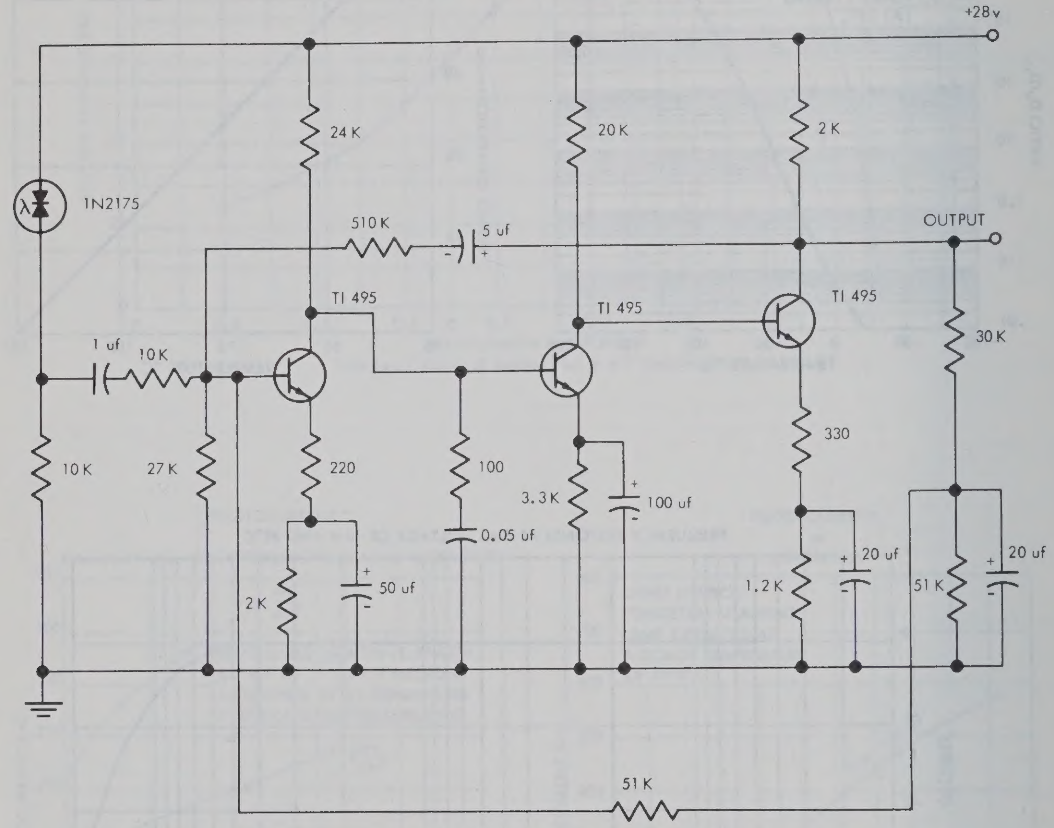
FREQUENCY RESPONSE AT BIAS VOLTAGE OF 10 V AND 25°C



LIGHT MODULATION FREQUENCY IN CYCLES PER SECOND
USING GLOW MODULATOR

PHOTO DUO-DIODE PREAMPLIFIER

This circuit was designed for use with the TI 1N2175 photo duo-diode. A voltage amplification of 30 db was obtained. This varied less than 1 db changing from low h_{FE} units at -40°C to high h_{FE} units at 100°C. An output of 4 volts peak to peak can be obtained across a 1 kΩ load resistor. The amplifier response is ±1 db from 10 cps to 10 kc.


+28 v
1N2175
λ
24 K
20 K
2 K
510 K
5 uf
OUTPUT
TI 495
TI 495
TI 495
1 uf
10 K
30 K
330
10 K
27 K
220
100
3.3 K
100 uf
0.05 uf
50 uf
2 K
1.2 K
20 uf
51 K
20 uf
51 K

Resistor values are in ohms.

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TI cannot assume any responsibility for any circuits shown or represent that they are free from patent infringement.

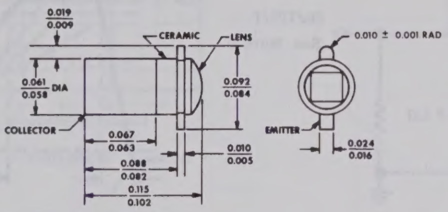
TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

TYPES 1N5722 THRU 1N5725
N-P-N PLANAR SILICON PHOTOTRANSISTORS

JEDEC-REGISTERED VERSIONS OF TIL601 THRU TIL604

- Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders
- Unique Package Design Allows for Assembly into Printed Circuit Boards

*mechanical data



ALL DIMENSIONS IN INCHES

FOUR TIMES
ACTUAL SIZE

*absolute maximum ratings at 25° C case temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25° C Case Temperature (See Note 1)	50 mW
Operating Case Temperature Range	–65°C to 125°C
Storage Temperature Range	–65°C to 150°C
Soldering Temperature (3 minutes)	240°C

*electrical characteristics at 25° C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 µA, H = 0	ALL	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 µA, H = 0	ALL	7			V
I_D	Dark Current	V_{CE} = 30 V, H = 0	ALL			25	nA
		V_{CE} = 30 V, H = 0, T_C = 100°C	ALL		1		µA
I_L	Light Current	V_{CE} = 5 V, H = 20 mW/cm^2, See Note 2	1N5722	0.5		3	mA
			1N5723	2		5	
			1N5724	4		8	
			1N5725	7			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA, H = 20 mW/cm^2, See Note 2	ALL		0.15		V

NOTES: 1. Derate linearly to 125° C at the rate of 0.5 mW/° C.
2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

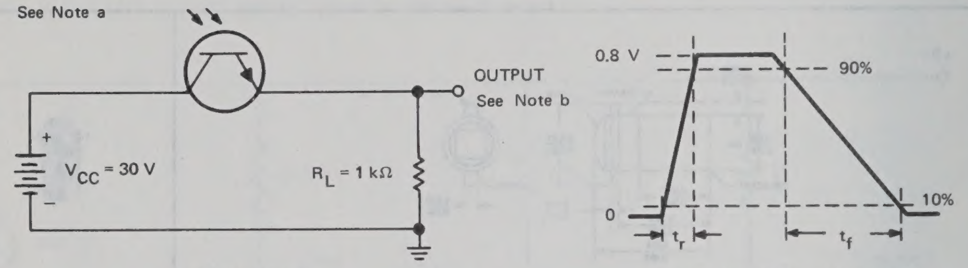
*JEDEC registered data. This data sheet contains all applicable JEDEC registered data in effect at the time of publication.

TYPES 1N5722 THRU 1N5725
N-P-N PLANAR SILICON PHOTOTRANSISTORS

*switching characteristics at 25° C case temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r Rise Time	$V_{CC} = 30$ V, $I_L = 800\ \mu A$, $R_L = 1\ k\Omega$, See Figure 1		1.5	2.5	μs
t_f Fall Time			15	25	

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irradiation is adjusted for $I_L = 800\ \mu A$.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

*JEDEC registered data

TYPICAL CHARACTERISTICS

COUPLING CHARACTERISTICS
vs
OF 1N5723 WITH TIL23 OR TIL24

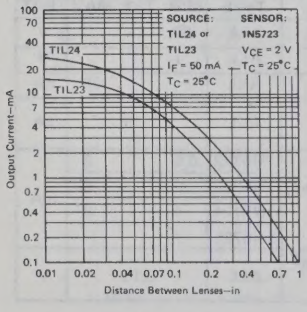


FIGURE 2

RELATIVE OUTPUT
vs
CASE TEMPERATURE OF SOURCE AND SENSOR

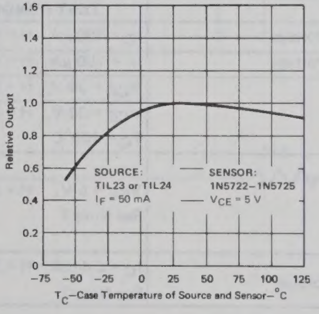


FIGURE 3

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

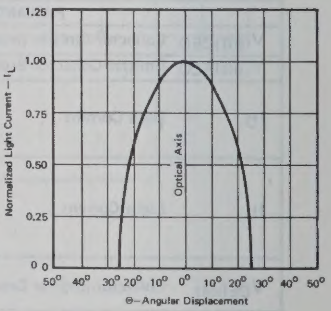


FIGURE 4

TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

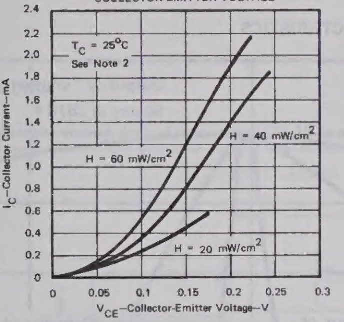


FIGURE 5

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

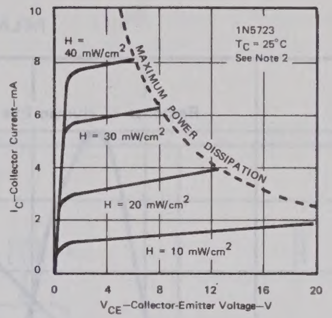


FIGURE 6

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

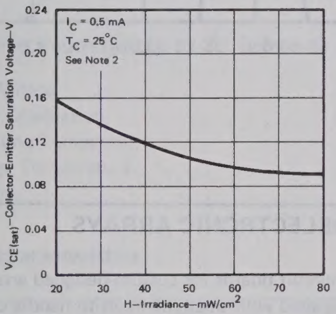


FIGURE 7

COLLECTOR CURRENT
vs
IRRADIANCE

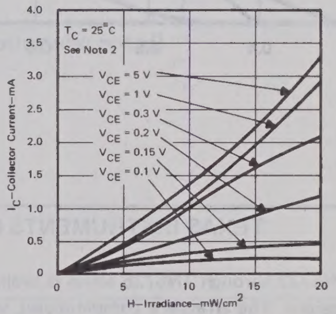


FIGURE 8

DARK CURRENT
vs
CASE TEMPERATURE

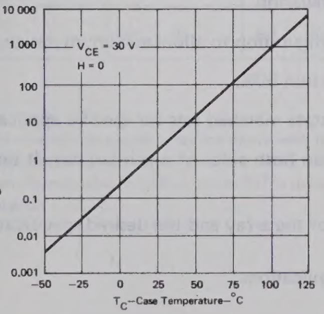


FIGURE 9

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

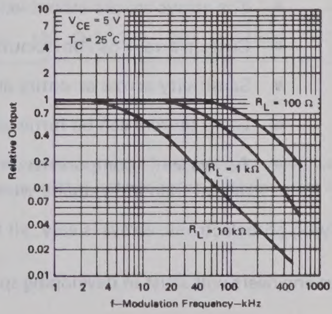


FIGURE 10

NOTE 2: Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TYPICAL CHARACTERISTICS

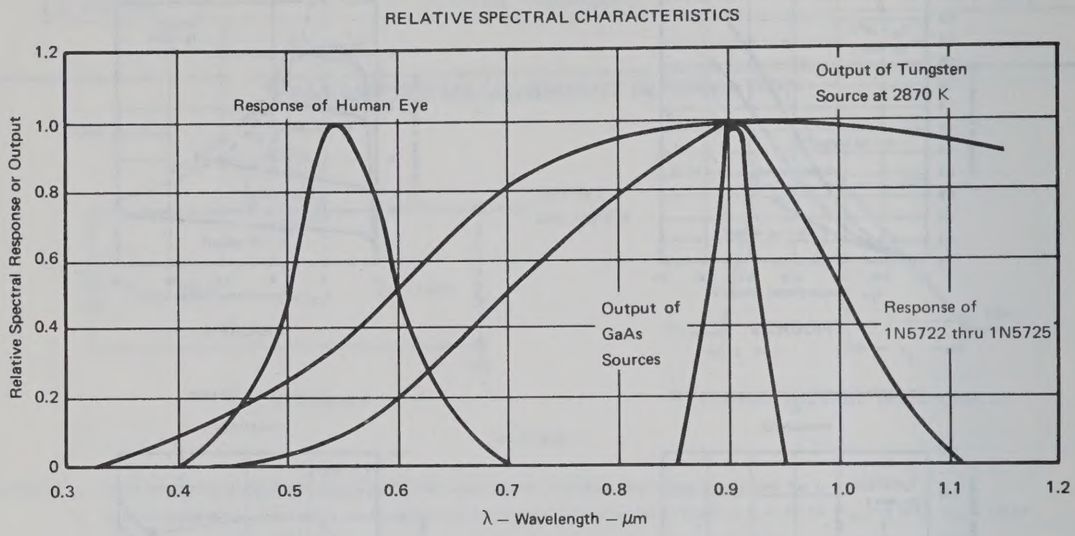


FIGURE 11

TEXAS INSTRUMENTS CUSTOMIZED OPTOELECTRONIC ARRAYS

The 1N5722 through 1N5725 series is available mounted in printed circuit boards for custom-designed array or matrix applications. The array is a complete unit, without the problems associated with small, difficult-to-handle components. These arrays can be designed for punched-card or tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

Texas Instruments custom-array techniques offer many advantages:

- The arrays are pre-assembled and tested, ready for installation.
- Custom arrays can be manufactured in almost any configuration to allow maximum design flexibility.
- Sensitivity across an entire array will be matched to within 50%.
- GaAs sources can be furnished to give complete solid-state matched sets for specific applications.
- Arrays with components firmly soldered into place on both sides of a printed circuit board are more rugged than individually wired sensing devices.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications.

TI sales engineers will assist in developing specifications for special applications.

Standard card-reader and tape-reader arrays are available.

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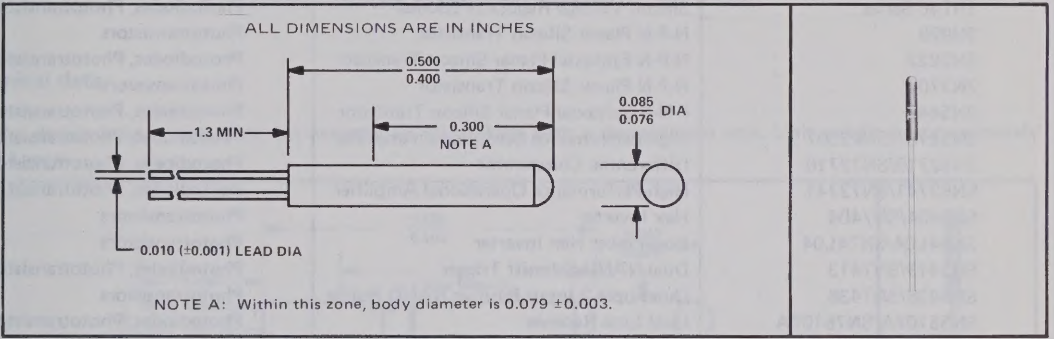
TYPES H-11, H-35, H-38, H-60, H-61, H-62
N-P-N DIFFUSED SILICON PHOTO DUO-DIODE

TYPES H-11, H-35, H-38, H-60, H-61, H-62
BULLETIN NO. DL-S 702927, JULY 1962
REVISED OCTOBER 1970

50 VOLTS • 50 MILLIWATTS
Designed for operation to 125°C

mechanical data

Hermetically sealed case. Unit weight 0.16 gram.


ALL DIMENSIONS ARE IN INCHES

NOTE A: Within this zone, body diameter is 0.079 ±0.003.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Bias Voltage	±50 V
Power Dissipation	50 mW
Operating Temperature	−65 to 125°C
Storage Temperature	−65 to 125°C
Altitude	70,000 ft

electrical characteristics

PARAMETER	H-11			H-35			H-38			H-60			H-61			H-62			UNIT
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
‡Dark Current @ 25°C, ±50 V		0.1	0.5		0.1	0.5		3.0	10		0.01	0.5		0.01	0.5		0.01	0.5	μA
Dark Current @ 100°C, ±50 V											20	100		20	100		20	100	μA
†Light Current @ 25°C, ±10 V	40	80		60	90		100	150		100	150	200	200	250	300	300	350	400	μA

‡Dark current is reverse current through the diode with no incident irradiation.

†Light current is measured with irradiance = 9 mW/cm^2 at a wavelength of 0.7 to 1.0 μm determined by a Corning CS7-69 filter. A two-hour light soak at an illumination of 40 to 80 lm/ft^2 is used prior to measurement of light current to approximate actual operating conditions and improve correlation.

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LIGHT SENSOR INTERFACE CHART

The following TI devices are commonly used in circuits for interfacing with light sensors. This interface chart is intended to be used for reference only since each circuit design is unique.

DEVICE TYPE	DESCRIPTION	USED WITH
1N746 Series	Silicon Voltage Regulator Diodes	Photodiodes, Phototransistors
2N929	N-P-N Planar Silicon Transistor	Phototransistors
2N2222	N-P-N Epitaxial Planar Silicon Transistor	Photodiodes, Phototransistors
2N3707	N-P-N Planar Silicon Transistor	Phototransistors
2N5447	P-N-P Epitaxial Planar Silicon Transistor	Photodiodes, Phototransistors
SN52107/SN72307	High-Performance Operational Amplifier	Photodiodes, Phototransistors
SN52710/SN72710	Differential Comparator	Photodiodes, Phototransistors
SN52741/SN72741	High-Performance Operational Amplifier	Photodiodes, Phototransistors
SN5404/SN7404	Hex Inverter	Phototransistors
SN54L04/SN74L04	Low-Power Hex Inverter	Phototransistors
SN5413/SN7413	Dual NAND Schmitt Trigger	Photodiodes, Phototransistors
SN5438/SN7438	Quadruple 2-Input Positive NAND Buffer	Phototransistors
SN55107A/SN75107A	Dual Line Receiver	Photodiodes, Phototransistors
SN75450/SN75450A	Dual Peripheral Driver	Photodiodes, Phototransistors
TIS98	N-P-N Epitaxial Planar Silicon Transistor	Photodiodes, Phototransistors

TYPE LS400
N-P-N PLANAR SILICON PHOTO TRANSISTOR

TYPE LS400
BULLETIN NO. DL-S 7111251, AUGUST 1969
REVISED JUNE 1971

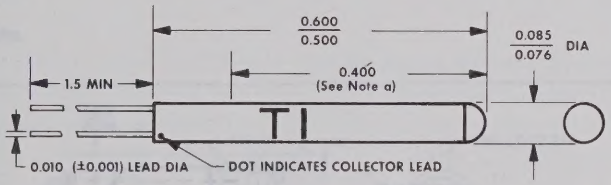
DESIGNED FOR APPLICATIONS IN CHARACTER RECOGNITION,
TAPE-READOUT, PHOTO SWITCHING, PROPORTIONAL CONTROL,
AND DIFFERENTIAL DETECTION

featuring

- Fast Switching Times
- Collector-Emitter Breakdown Voltage . . . 50 V Min

mechanical data

The device is in a hard glass, hermetically sealed package with a dome-shaped lens. Unit weight is approximately 0.1 gram.



NOTES: a. Within this zone, body diameter is 0.079 ± 0.003
b. All dimensions are in inches.

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	6 V
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 1)	50 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_D	Dark Current	V_{CE} = 30 V, H = 0		10	25	nA
		V_{CE} = 30 V, H = 0, T_C = 100°C		10	15	μA
I_L	Light Current	V_{CE} = 5 V, H = 9 mW/cm², See Note 2	1	3		mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA, H = 9 mW/cm², See Note 2		0.3		V

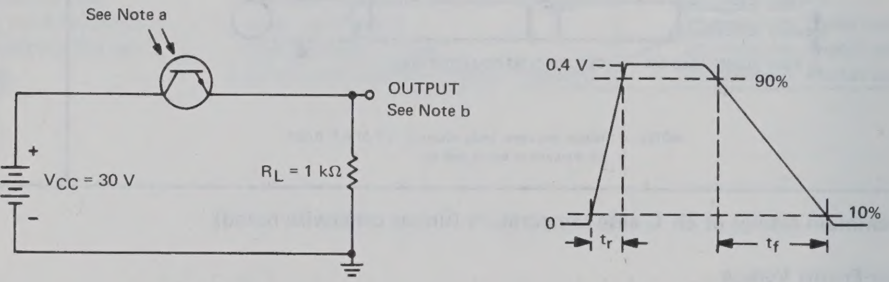
NOTES: 1. Derate linearly to 125°C case temperature at the rate of 0.5 mW/°C.
2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is a tungsten-filament bulb. The wavelength is 0.7 to 1.0 μm determined by a Corning CS7-69 filter.

TYPE LS400
N-P-N PLANAR SILICON PHOTO TRANSISTOR

switching characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 30$ V, $I_L = 400\ \mu$A, $R_L = 1$ kΩ, See Figure 1	1.5	μs
t_f	Fall Time		15	μs

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irridation is adjusted for $I_L = 400\ \mu$A.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 25$ ns, $R_{in} \geq 1$ MΩ, $C_{in} \leq 20$ pF.

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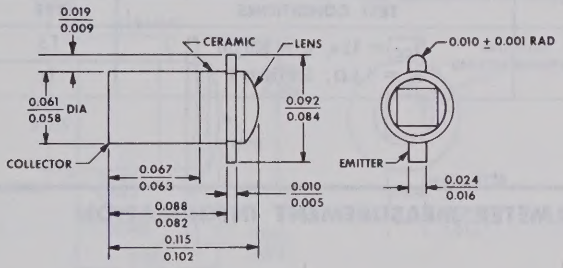
TYPE LS600
N-P-N PLANAR SILICON LIGHT SENSOR

TYPE LS600
BULLETIN NO. DL-S 693820, JUNE 1963
REVISED AUGUST 1969

MICRO SENSOR DESIGNED FOR HIGH-DENSITY MATRIX AND LINE READ-OUT EQUIPMENT

- Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders
- Unique Package Design Allows for Assembly into Printed Circuit Boards
- Small Diameter Reduces Optical "Cross-Talk"
- Power Dissipation 50 mw

mechanical data


0.019
0.009
CERAMIC
LENS
0.010 ± 0.001 RAD
0.061
0.058
DIA
0.092
0.084
COLLECTOR
EMITTER
0.067
0.063
0.010
0.005
0.024
0.016
0.088
0.082
0.115
0.102

ALL DIMENSIONS IN INCHES

FOUR TIMES ACTUAL SIZE

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 v
Emitter-Collector Voltage	7 v
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	50 mw
Operating Free-Air Temperature Range	−65°C to +125°C
Storage Temperature Range	−65°C to +150°C
Soldering Temperature (3 minutes)	240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 0.5 mw/°C.

TYPE LS600
N-P-N PLANAR SILICON LIGHT SENSOR

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

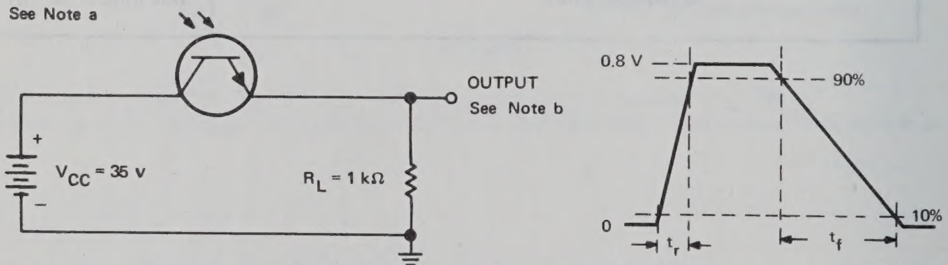
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_L	Light Current	$V_{CE} = 5$ v, $H = 20$ mw/cm^2 See Note 2	0.8	1.0		ma
I_D	Dark Current	$V_{CE} = 30$ v, $H = 0$		0.01	0.025	μa
I_D	Dark Current	$V_{CE} = 30$ v, $H = 0$ $T_A = 100$°C		10		μa
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_L = 0.4$ ma, $H = 20$ mw/cm^2 See Note 2		0.3		v

NOTE 2: Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear filament bulb operating at 2870°K color temperature.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 35$ v, $I_L = 800$ μa $R_L = 1$ kΩ, See Figure 1	1.5	μsec
t_f	Fall Time		15	μsec

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irridation is adjusted for $I_L = 800$ μa.

b. Output waveform is monitored on an oscilloscope with the following characteristics:

$t_r \leq 25$ nsec, $R_{in} \geq 1$ megohm, $C_{in} \leq 20$ pf.

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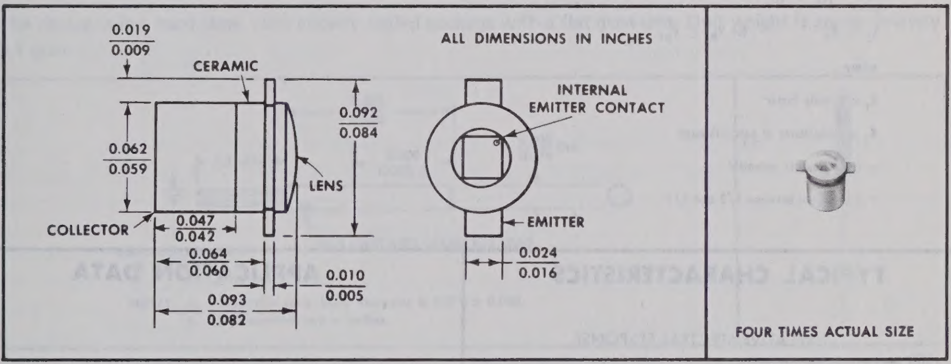
TYPE LSX900
P-N EPITAXIAL PLANAR SILICON LASER DETECTOR

TYPE LSX900
BULLETIN NO. DL-S 705076, MARCH 1964
REVISED OCTOBER 1970

PHOTOCONDUCTIVE OR PHOTOVOLTAIC LIGHT SENSOR DESIGNED TO OPERATE AT MICROWAVE FREQUENCIES

- **Recommended for light demodulation up to 2 Gc**
- **Unique pill package design allows mounting in coaxial microwave structures**

mechanical data


0.019
0.009
CERAMIC
ALL DIMENSIONS IN INCHES
INTERNAL EMITTER CONTACT
0.092
0.084
0.062
0.059
LENS
COLLECTOR
0.047
0.042
0.064
0.060
0.010
0.005
0.093
0.082
EMITTER
0.024
0.016
FOUR TIMES ACTUAL SIZE

absolute maximum ratings

Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	50 mw
Operating Free-Air Temperature Range	−65°C to +125°C
Storage Temperature Range	−65°C to +150°C
Soldering Temperature (3 minutes)	240°C

NOTE 1. Derate linearly to 125°C free-air temperature at the rate of 0.5 mw/C°.

TYPE LSX900
P-N EPITAXIAL PLANAR SILICON LASER DETECTOR

3

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
BV_R	Breakdown Voltage	$I_R = 100\ \mu a$	125	140		v
I_L	Light Current	$V_R = 30$ v, $H = 20$ mw/cm², See Note 2	6	7.8		μa
I_D	Dark Current	$V_R = 50$ v, $H = 0$, See Note 3		0.3	9	na
C_j	Junction Capacitance†	$V_R = 10$ v, $f = 1$ Mc		2.9		pf
C_j	Junction Capacitance†	$V_R \geq V_{pt} \approx 60$ v, $f = 1$ Mc		1.7		pf

NOTES: 2. Irradiance (H) is the radiant power unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear filament bulb operating at 2870°K color temperature.

3. Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

†Below punch-through, junction capacitance is approximately inversely proportional to the square root of reverse voltage and is constant above punch-through as shown by the following equations:

$$C_j = \frac{K_1}{(V_R + \phi)^n} \quad \text{for } V_R < V_{pt}$$

$$C_j = K_2 \quad \text{for } V_R \geq V_{pt}$$

where:

K_1 is a scale factor

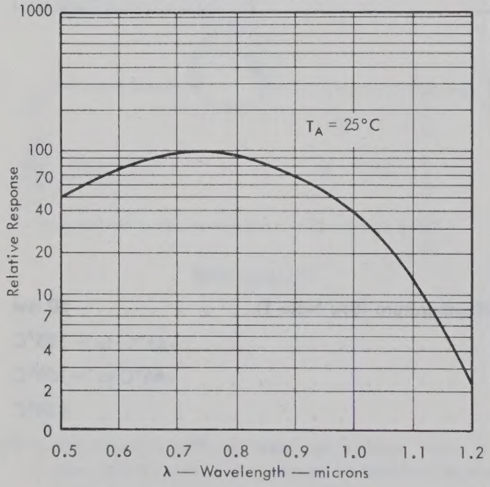
K_2 is capacitance at punch-through

ϕ is the contact potential

n is a number between 1/2 and 1/3

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL RESPONSE



APPLICATION DATA

Use conjugate match between diode and load (Reference 1).
Signal to noise may be improved by operation in avalanche mode but 50 mw dissipation must not be exceeded (Reference 2).

REFERENCES

1. Johnson, Kenneth M. "Performance of the Photovoltaic Effect Detector Diode as a Microwave Demodulator of Light," The Microwave Journal, July, 1963.
2. Johnson, Kenneth M. "Photodiode Signal Enhancement Effect at Avalanche Breakdown Voltage," Digest of Technical Papers, International Solid State Circuits Conference, February, 1964.

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TYPE TIL58
N-P-N PLANAR SILICON PHOTO TRANSISTOR

TYPE TIL58
BULLETIN NO. DL-S 6911222, MARCH 1969

FLAT-LENS LIGHT SENSOR

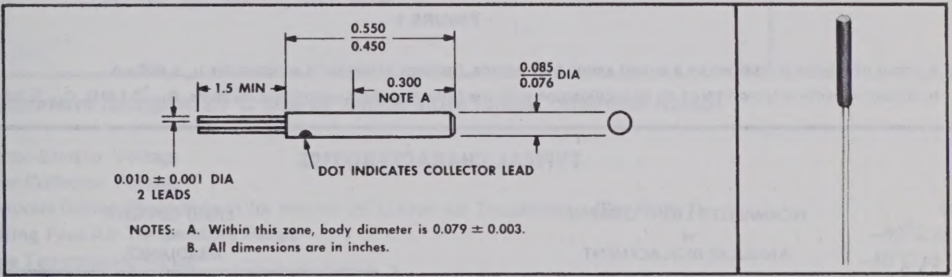
Designed for Applications in Character Recognition, Tape-Readout, Photo Switching, Proportional Control, and Differential Detection

featuring

- **Wide-Angle Sensitivity . . . Typically 90° between Half-Power Points**
- **Elimination of Need for Optimum-Sensitivity Alignment**
- **Fast Switching Times**
- **Collector-Emitter Breakdown Voltage . . . 50 V Min**

mechanical data

The device is in a hard glass, hermetically sealed package with a flat glass lens. Unit weight is approximately 0.1 gram.



NOTES: A. Within this zone, body diameter is 0.079 ± 0.003.
B. All dimensions are in inches.

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	6 V
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 1)	50 mW
Operating Case Temperature Range	-65°C to 125°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_D	Dark Current	$V_{CE} = 30$ V, $H = 0$			25	nA
		$V_{CE} = 30$ V, $H = 0$, $T_C = 100°C$			10	µA
I_L	Light Current	$V_{CE} = 5$ V, $H = 20$ mW/cm^2, See Note 2	1	2		mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 0.4$ mA, $H = 20$ mW/cm^2, See Note 2		0.3		V

NOTES: 1. Derate linearly to 125°C case temperature at the rate of 0.5 mW/°C.
2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament bulb operating at a color temperature of 2870 K.

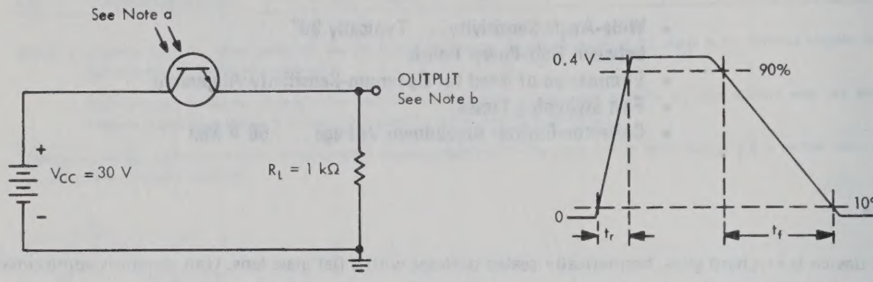
TYPE TIL58
N-P-N PLANAR SILICON PHOTO TRANSISTOR

3

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 30$ V, $I_L = 400$ µA, $R_L = 1$ kΩ, See Figure 1	1.5	µs
t_f	Fall Time		15	µs

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irridation is adjusted for $I_L = 400$ µA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 25$ ns, $R_{in} \geq 1$ MΩ, $C_{in} \leq 20$ pF.

TYPICAL CHARACTERISTICS

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

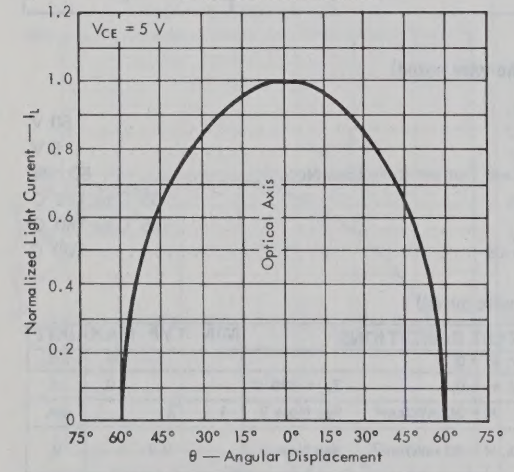


FIGURE 2

LIGHT CURRENT
vs
IRRADIANCE

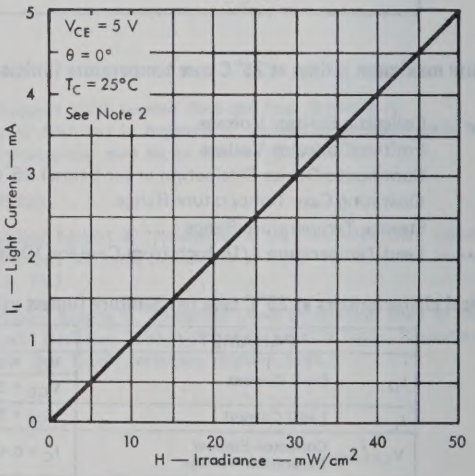


FIGURE 3

NOTE: 2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament bulb operating at a color temperature of 2870 K.

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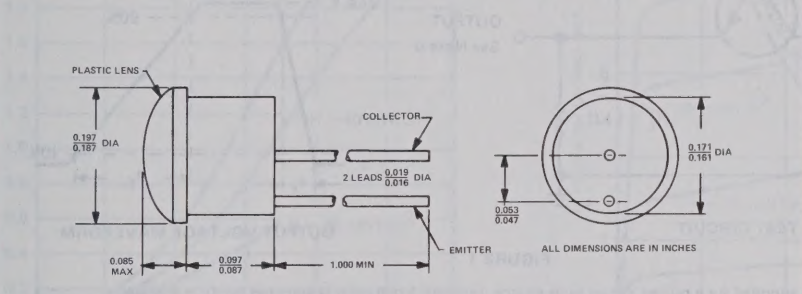
TYPES TIL63 THRU TIL67
N-P-N PLANAR SILICON PHOTOTRANSISTORS

TYPES TIL63 THRU TIL67
BULLETIN NO. DL-S 6911291, DECEMBER 1969

- Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders
- Epoxy Dome-Shaped Lens
- Glass-to-Metal-Seal Header

mechanical data

BOTH LEADS ELECTRICALLY INSULATED FROM CASE



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	50 mW
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 μA, H = 0	ALL	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 μA, H = 0	ALL	7			V
I_D	Dark Current	V_{CE} = 30 V, H = 0	ALL			25	nA
		V_{CE} = 30 V, H = 0, T_A = 80°C	ALL		0.5		μA
I_L	Light Current	V_{CE} = 5 V, H = 20 mW/cm^2, See Note 2	TIL63	0.4			mA
			TIL64	0.4		1.6	
			TIL65	1		4	
			TIL66	2.5		10	
			TIL67	6			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA, H = 20 mW/cm^2, See Note 2	ALL		0.15		V

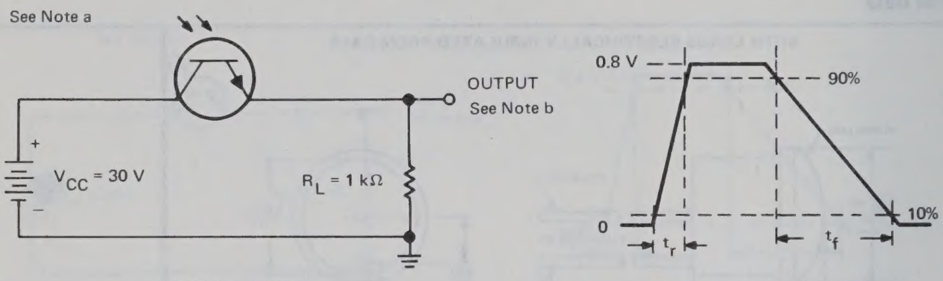
NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 30$ V, $I_L = 800$ μA, $R_L = 1$ kΩ, See Figure 1	1.5	μs
t_f	Fall Time		15	

PARAMETER MEASUREMENT INFORMATION


See Note a
OUTPUT
See Note b
$V_{CC} = 30$ V
+
−
$R_L = 1$ kΩ
0.8 V
90%
10%
0
t_r
t_f

TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irradiation is adjusted for $I_L = 800$ μA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

TYPICAL APPLICATION DATA

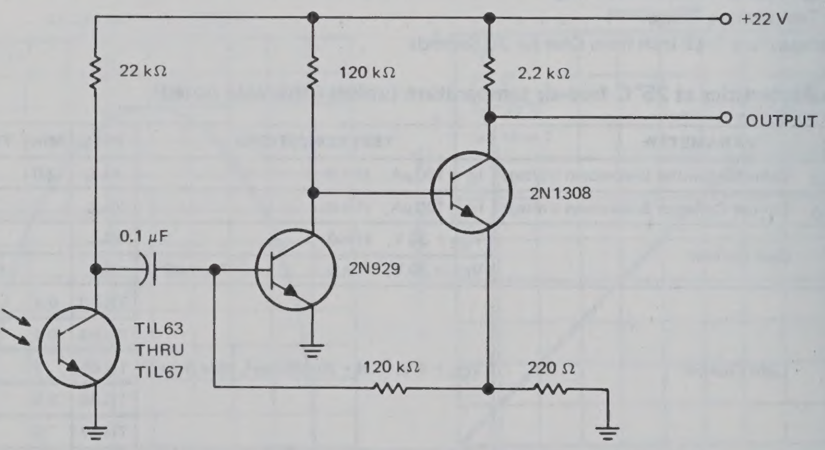

+22 V
22 kΩ
120 kΩ
2.2 kΩ
OUTPUT
2N1308
0.1 μF
2N929
TIL63
THRU
TIL67
120 kΩ
220 Ω

FIGURE 2—LIGHT PULSE DETECTOR

TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

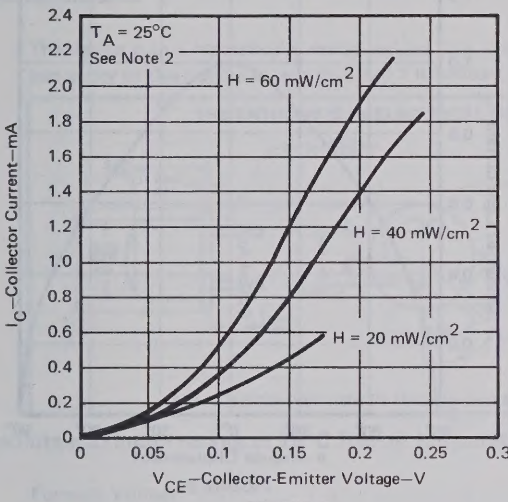


FIGURE 3

TIL65
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

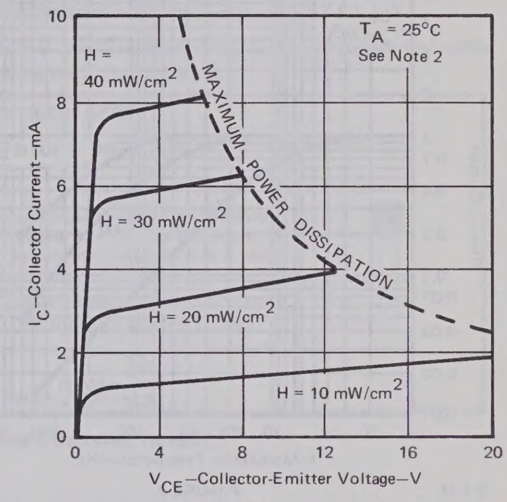


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

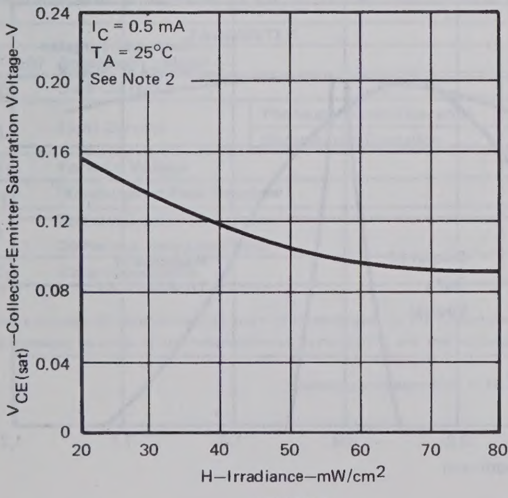


FIGURE 5

DARK CURRENT
vs
FREE-AIR TEMPERATURE

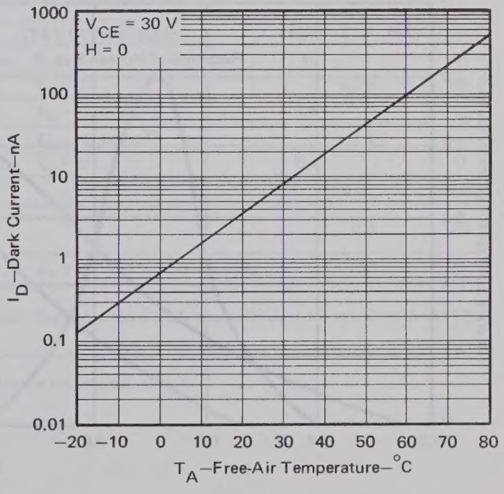


FIGURE 6

NOTE: 2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870°K.

TYPICAL CHARACTERISTICS

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

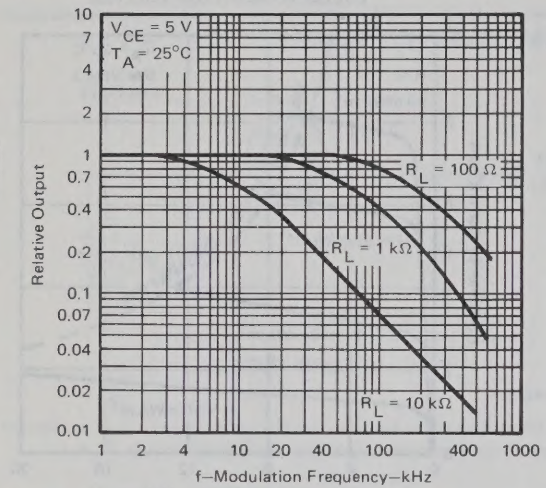


FIGURE 7

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

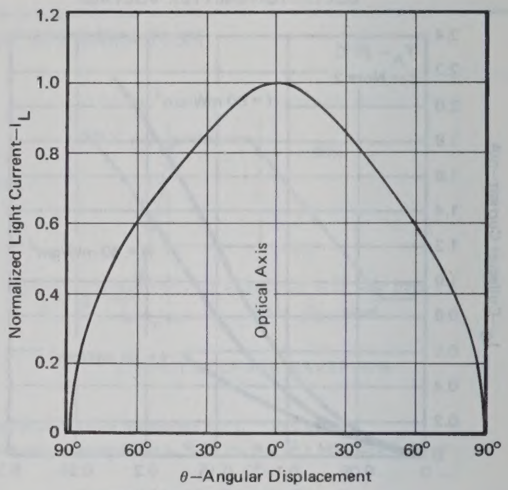


FIGURE 8

RELATIVE SPECTRAL CHARACTERISTICS

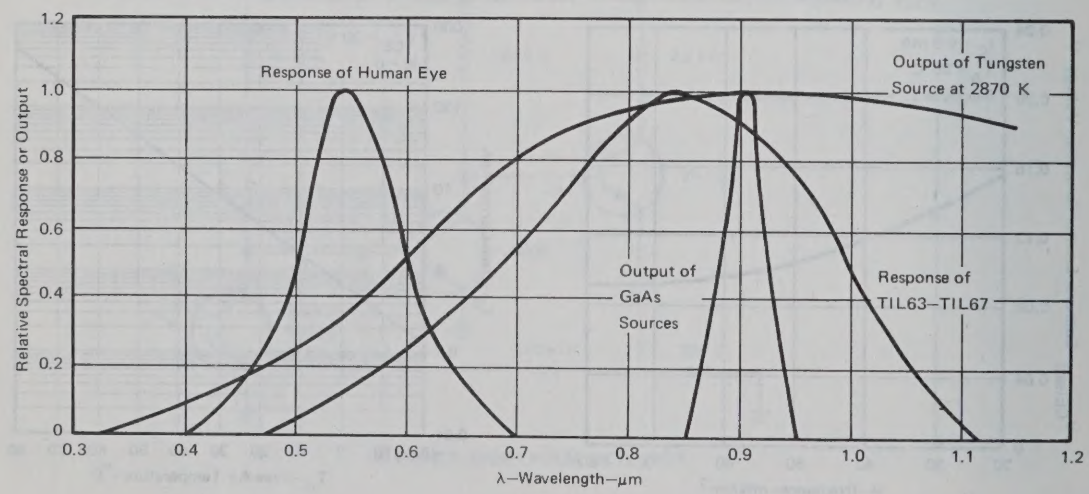


FIGURE 9

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TYPE TIL77
P-N SILICON PHOTODIODE

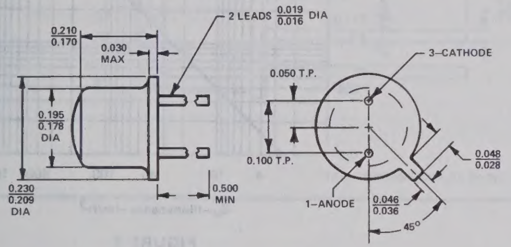
DESIGNED TO DETECT LIGHT IN THE VISIBLE SPECTRUM

- Output Is Linear with Illumination
- High Light-to-Dark Current Ratio
- Capable of Operation in Photoconductive or Photovoltaic Mode

mechanical data

The device is in a hermetically sealed welded case similar to JEDEC TO-18 with window. All TO-18 registration notes also apply to this outline except that lead 2 is omitted. Approximate weight is 0.35 gram.

THE CATHODE IS IN ELECTRICAL CONTACT WITH THE CASE



MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.010, MINIMUM DIAMETER IS 0.150

THE LENS IS CORNING 7052 (OR EQUIVALENT) GLASS

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Forward Voltage	0.4 V
Reverse Voltage	10 V
Operating Free-Air Temperature Range	–20°C to 80°C
Storage Temperature Range	–20°C to 80°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)}$	Breakdown Voltage		$I_R = 10\ \mu A$, $E_v = 0$	10			V
I_D	Dark Current		$V_R = 3\ V$, $E_v = 0$		0.25	5	nA
I_L	Light Current	Photoconductive Operation	$V_R = 3\ V$, $E_v = 50\ lm/ft^{2\dagger}$	1.5	2		μA
		Photovoltaic Operation	$V_R = 0$, $E_v = 50\ lm/ft^{2\dagger}$		2		
V_F	Forward Voltage		$I_F = 10\ \mu A$, $E_v = 0$	0.4			V
λ_p	Wavelength at Peak Response				0.57		μm
B	Spectral Bandwidth between 20-Percent Response Points		$V_R = 3\ V$		0.3		μm
C_T	Total Capacitance		$V_R = 3\ V$, $E_v = 0$, f = 1 MHz		750		pF

†The common British-American unit of illumination is the lumen per square foot. The name footcandle has been used for this unit in the USA. To convert to units of the International System (SI), use the equivalency:

1 lumen per square foot = 10.764 lux (lumens per square meter).

TYPE TIL77
P-N SILICON PHOTODIODE

TYPICAL CHARACTERISTICS

DARK CURRENT
vs
FREE-AIR TEMPERATURE

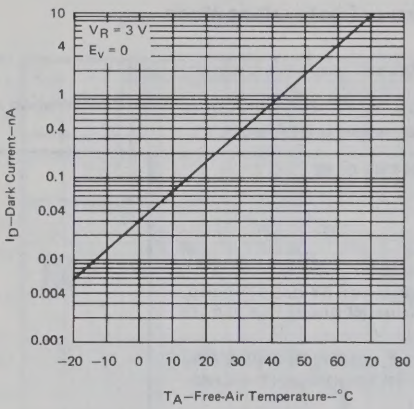


FIGURE 1

LIGHT CURRENT
vs
ILLUMINANCE

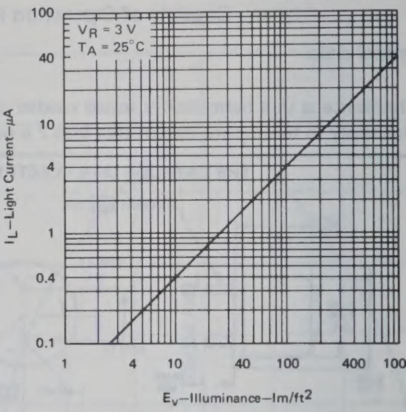


FIGURE 2

RELATIVE SPECTRAL CHARACTERISTICS

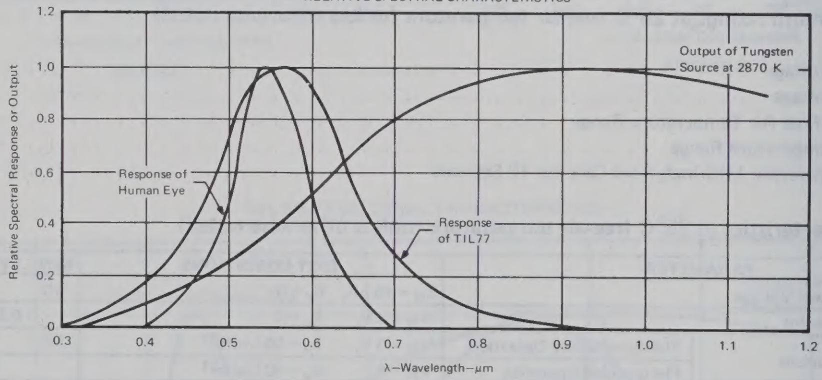
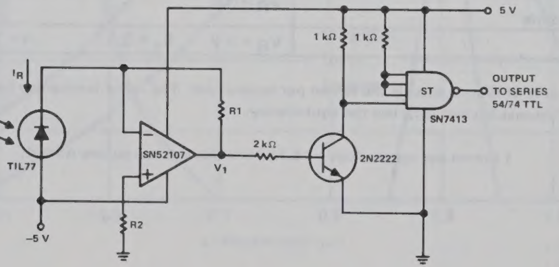


FIGURE 3

TYPICAL APPLICATION DATA



5 V
1 kΩ
1 kΩ
I_R
R1
OUTPUT
TO SERIES
54/74 TTL
ST
SN7413
SN52107
2 kΩ
2N2222
V_1
TIL77
R2
−5 V

Photodiode amplifier output voltage, V_1, is equal to R1 • I_R. Select R1 for desired threshold voltage. R2 = R1.

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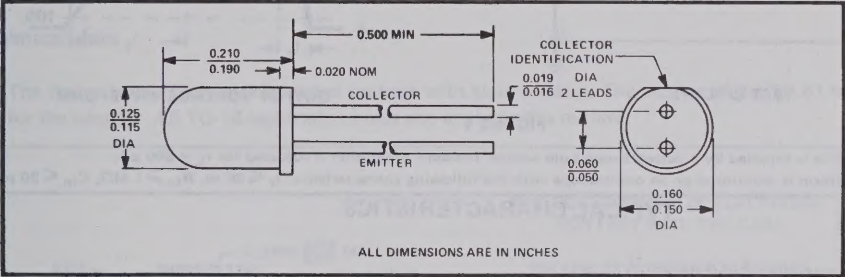
TYPE TIL78
N-P-N SILICON PHOTOTRANSISTOR

TYPE TIL78
BULLETIN NO. DL-S 7111549, SEPTEMBER 1971

- Designed for Automatic or Hand Insertion in Sockets or PC Boards
- Recommended for Industrial Applications Requiring Low-Cost Discrete Phototransistors
- Spectrally and Mechanically Matched with TIL32 IR Emitter.

mechanical data

This device has a clear molded epoxy body with silver-plated dumet leads.



ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	50 mW
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	240°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

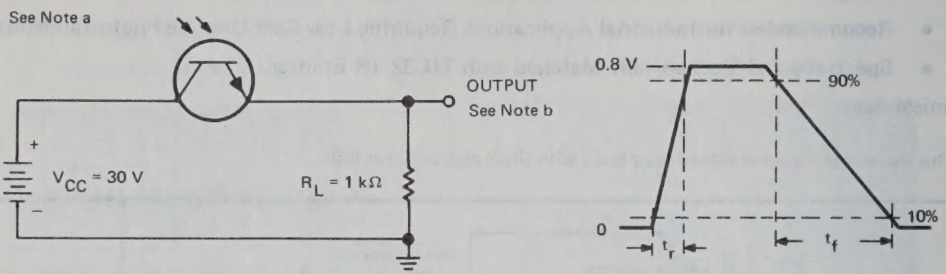
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 µA, H = 0		50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 µA, H = 0		7			V
I_D	Dark Current	V_{CE} = 30 V, H = 0				25	nA
		V_{CE} = 30 V, H = 0, T_A = 80°C			1		µA
I_L	Light Current	V_{CE} = 5 V, H = 20 mW/cm^2	See Note 2	1	7		mA
		V_{CE} = 5 V, H = 2 mW/cm^2			0.5		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 2 mA, H = 20 mW/cm^2,	See Note 2		0.4		V

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	V_{CC} = 30 V, I_L = 800 µA,	1.5	µs
t_f	Fall Time	R_L = 1 kΩ, See Figure 1	15	

NOTES:
1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.
2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irradiation is adjusted for $I_L = 800\ \mu A$.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

TYPICAL CHARACTERISTICS

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

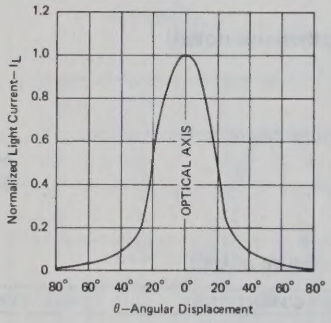


FIGURE 1

DARK CURRENT
vs
FREE-AIR TEMPERATURE

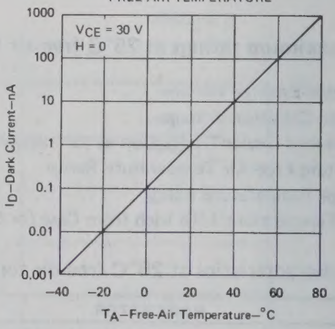


FIGURE 2

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

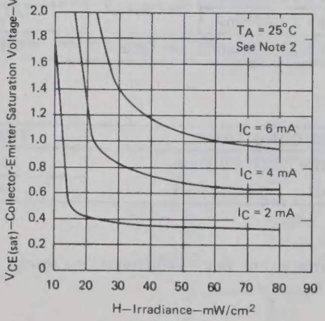


FIGURE 3

COUPLING CHARACTERISTICS
OF
TIL32 WITH TIL78

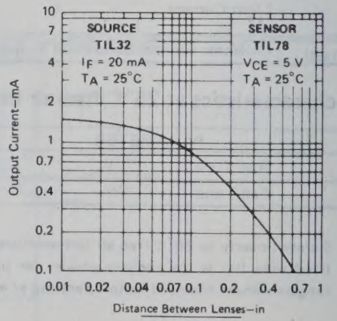


FIGURE 4

NOTE 2: Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

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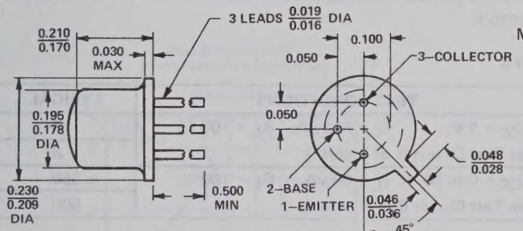
TYPE TIL81
N-P-N PLANAR SILICON PHOTOTRANSISTOR

- Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders
- Spectrally and Mechanically Matched with TIL31 IR Emitter
- Glass-to-Metal-Seal Header
- Base Contact Externally Available
- Saturation Level Directly Compatible with Most TTL/DTL

mechanical data

The device is in a hermetically sealed package with glass window. The outline of the TIL81 is similar to TO-18 except for the window. All TO-18 registration notes also apply to this outline



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.070, MINIMUM DIAMETER IS 0.125

THE LENS IS CORNING 7052 GLASS (OR EQUIVALENT)

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	50 V
Collector-Emitter Voltage	30 V
Emitter-Base Voltage	7 V
Emitter-Collector Voltage	7 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	250 mW
Operating Free-Air Temperature Range	–65°C to 125°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 2.5 mW/°C.

TYPE TIL81
N-P-N PLANAR SILICON PHOTOTRANSISTOR

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

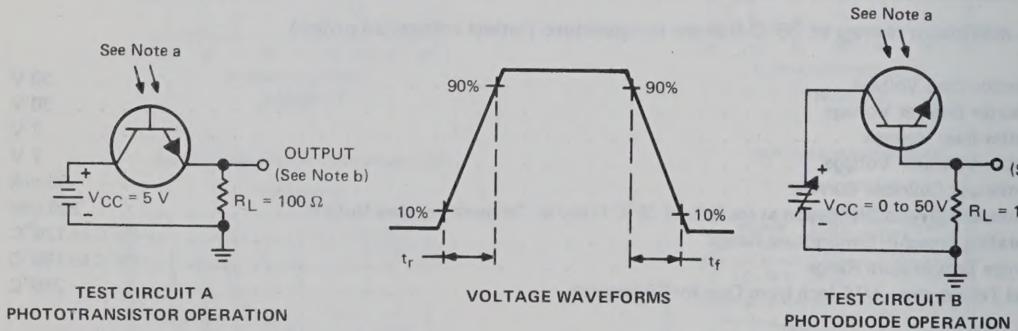
PARAMETER			TEST CONDITIONS			MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 100\ \mu A$,	$I_E = 0$,	$H = 0$	50			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 100\ \mu A$,	$I_B = 0$,	$H = 0$	30			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 100\ \mu A$,	$I_C = 0$,	$H = 0$	7			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage		$I_E = 100\ \mu A$,	$I_B = 0$,	$H = 0$	7			V
I_D	Dark Current	Phototransistor Operation	$V_{CE} = 10$ V,	$I_B = 0$,	$H = 0$			0.1	µA
			$V_{CE} = 10$ V, $T_A = 100°C$	$I_B = 0$,	$H = 0$,		20		
		Photodiode Operation	$V_{CB} = 10$ V,	$I_E = 0$,	$H = 0$			0.01	µA
I_L	Light Current	Phototransistor Operation	$V_{CE} = 5$ V, See Note 2	$I_B = 0$,	$H = 5\ mW/cm^2$,	5	22		mA
		Photodiode Operation	$V_{CB} = 0$ to 50 V, See Note 2	$I_E = 0$,	$H = 20\ mW/cm^2$,		170		µA
h_{FE}	Static Forward Current Transfer Ratio		$V_{CE} = 5$ V,	$I_C = 1$ mA,	$H = 0$		200		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 2$ mA, See Note 2	$I_B = 0$,	$H = 20\ mW/cm^2$,		0.2		V

NOTE 2: Irradiance (H) is the radiant power per unit area incident upon a surface. For these measurements the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TYPICAL	UNIT
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 5$ V, $I_L = 800\ \mu A$, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1	8	µs
t_f	Fall Time			6	
t_r	Rise Time	Photodiode Operation	$V_{CC} = 0$ to 50 V, $I_L = 60\ \mu A$, $R_L = 100\ \Omega$, See Test Circuit B of Figure 1	350	ns
t_f	Fall Time			500	

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION

VOLTAGE WAVEFORMS

TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide light source with a rise time less than 50 nanoseconds. Incident irradiation is adjusted for specified I_L.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

FIGURE 1

TYPICAL CHARACTERISTICS

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

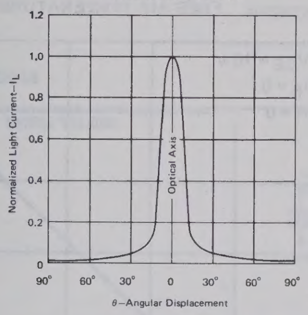


FIGURE 2

COUPLING CHARACTERISTICS
OF
TIL31 WITH TIL81

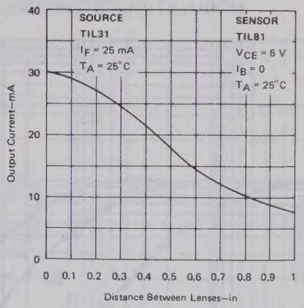


FIGURE 3

COLLECTOR CURRENT
(PHOTOTRANSISTOR OPERATION)
vs
IRRADIANCE

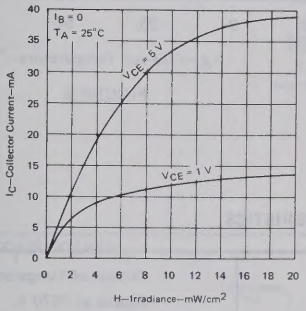


FIGURE 4

COLLECTOR CURRENT
(PHOTODIODE OPERATION)
vs
COLLECTOR-EMITTER VOLTAGE

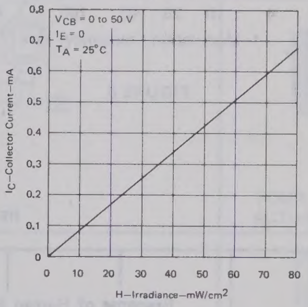


FIGURE 5

COLLECTOR CURRENT
(PHOTOTRANSISTOR OPERATION)
vs
COLLECTOR-EMITTER VOLTAGE

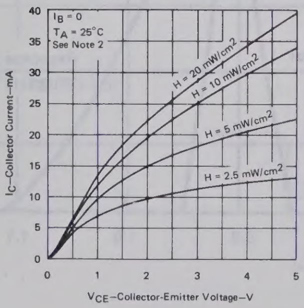


FIGURE 6

COLLECTOR-EMITTER
SATURATION VOLTAGE
vs
COLLECTOR CURRENT

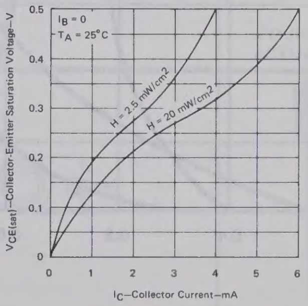


FIGURE 7

NOTE 2: Irradiance (H) is the radiant power per unit area incident upon a surface. For these measurements the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TYPICAL CHARACTERISTICS

RELATIVE OUTPUT
(PHOTOTRANSISTOR OPERATION)
vs
MODULATION FREQUENCY

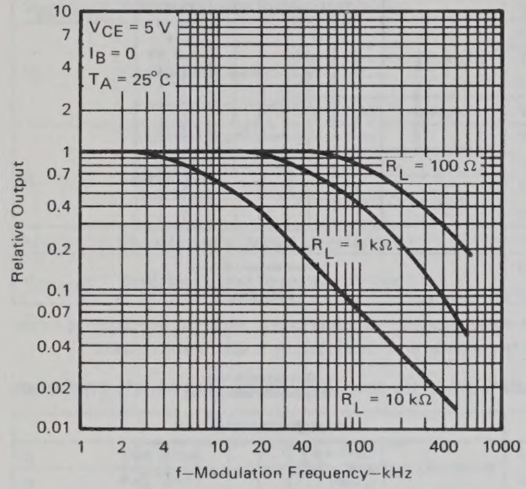


FIGURE 8

NORMALIZED DARK CURRENT
vs
FREE-AIR TEMPERATURE

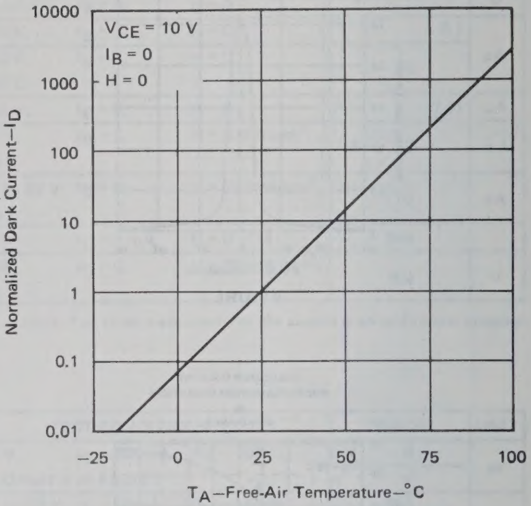


FIGURE 9

RELATIVE SPECTRAL CHARACTERISTICS

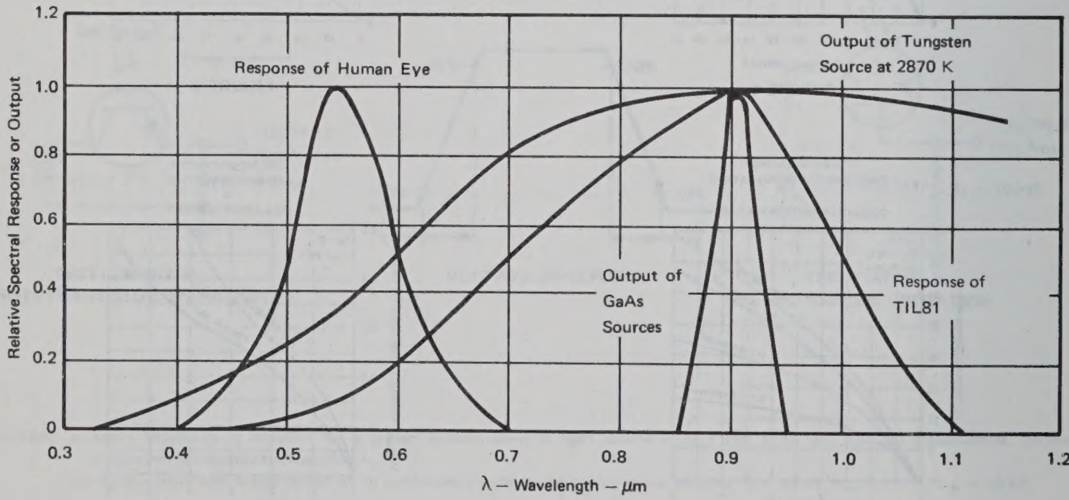


FIGURE 10

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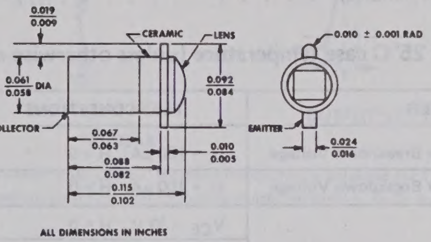
TYPES TIL601 THRU TIL616
BULLETIN NO. DL-S 6911234, JULY 1969

- Designed for High-Density Read Out
- Improved and Repackaged Versions of LS600

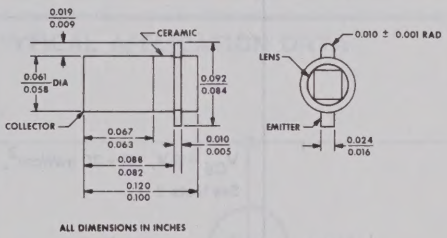
mechanical data

TIL601 THRU TIL604


0.019
0.009
CERAMIC
LENS
0.010 ± 0.001 RAD
0.061
0.058
DIA
0.092
0.084
COLLECTOR
EMITTER
0.067
0.063
0.010
0.005
0.024
0.016
0.088
0.082
0.115
0.102
ALL DIMENSIONS IN INCHES

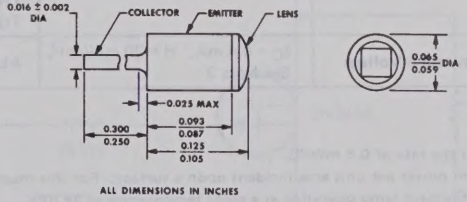
FOUR TIMES
ACTUAL SIZE

TIL605 THRU TIL608


0.019
0.009
CERAMIC
0.010 ± 0.001 RAD
LENS
0.061
0.058
DIA
0.092
0.084
COLLECTOR
EMITTER
0.067
0.063
0.010
0.005
0.024
0.016
0.088
0.082
0.120
0.100
ALL DIMENSIONS IN INCHES

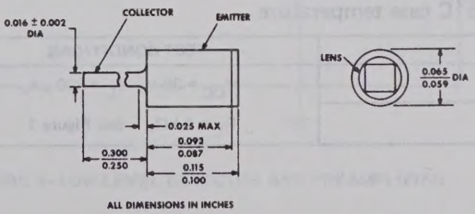
FOUR TIMES
ACTUAL SIZE

TIL609 THRU TIL612


0.016 ± 0.002
DIA
COLLECTOR
EMITTER
LENS
0.065
0.059
DIA
0.025 MAX
0.093
0.087
0.300
0.250
0.125
0.105
ALL DIMENSIONS IN INCHES

FOUR TIMES
ACTUAL SIZE

TIL613 THRU TIL616


COLLECTOR
EMITTER
0.016 ± 0.002
DIA
LENS
0.065
0.059
DIA
0.025 MAX
0.093
0.087
0.300
0.250
0.115
0.100
ALL DIMENSIONS IN INCHES

FOUR TIMES
ACTUAL SIZE

TYPES TIL601 THRU TIL616
N-P-N PLANAR SILICON PHOTOTRANSISTORS

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 1)	50 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (3 minutes)	240°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $H = 0$	ALL	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $H = 0$	ALL	7			V
I_D	Dark Current	$V_{CE} = 30$ V, $H = 0$	ALL			25	nA
		$V_{CE} = 30$ V, $H = 0$, $T_C = 100°C$	ALL		1		μA
I_L	Light Current	$V_{CE} = 5$ V, $H = 20\ mW/cm^2$, See Note 2	TIL601 TIL605 TIL609 TIL613	0.5		3	mA
			TIL602 TIL606 TIL610 TIL614	2		5	mA
			TIL603 TIL607 TIL611 TIL615	4		8	mA
			TIL604 TIL608 TIL612 TIL616	7			mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 0.4$ mA, $H = 20\ mW/cm^2$, See Note 2	ALL		0.15		V

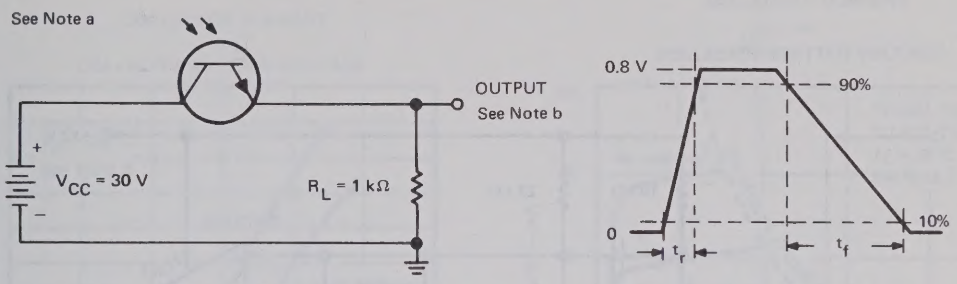
NOTES: 1. Derate linearly to 125°C at the rate of 0.5 mW/°C.

2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870°K.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 30$ V, $I_L = 800\ \mu A$, $R_L = 1\ k\Omega$, See Figure 1	1.5	μs
t_f	Fall Time		15	

PARAMETER MEASUREMENT INFORMATION


See Note a
OUTPUT
See Note b
+
V_{CC} = 30 V
−
R_L = 1 kΩ
0.8 V
90%
0
10%
t_r
t_f

TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irradiation is adjusted for I_L = 800 μA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

TYPICAL APPLICATION DATA

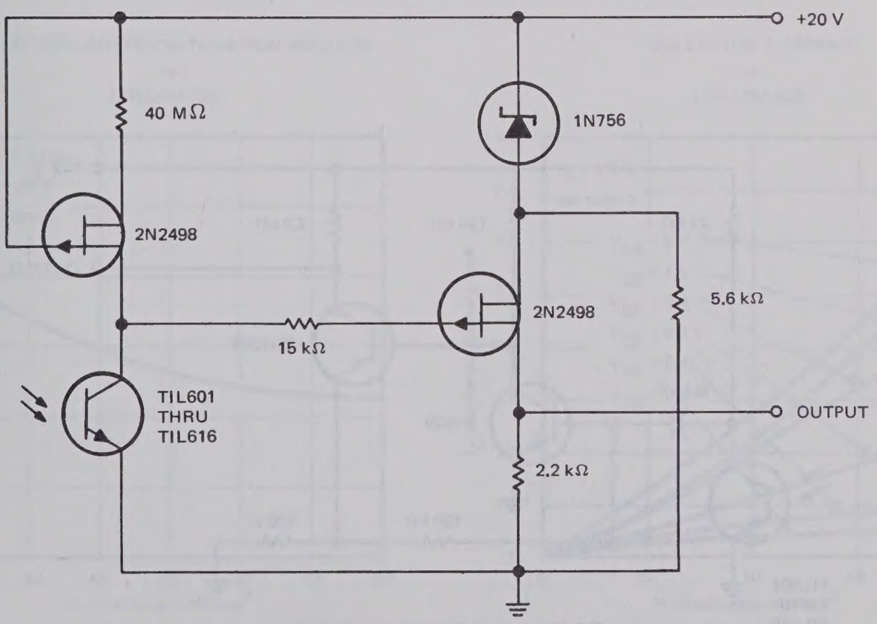

+20 V
40 MΩ
1N756
2N2498
5.6 kΩ
2N2498
15 kΩ
TIL601
THRU
TIL616
OUTPUT
2.2 kΩ

FIGURE 2—LOW-LEVEL DETECTOR AND PREAMPLIFIER

TYPICAL APPLICATION DATA

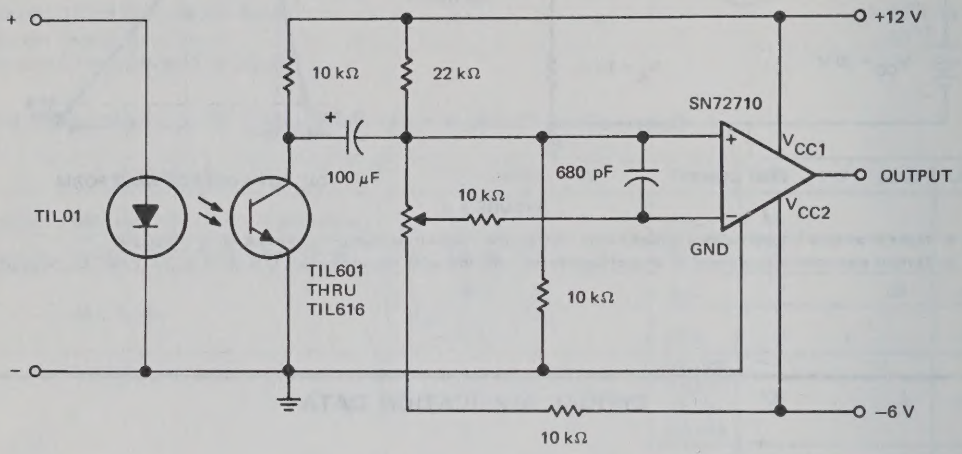

+
−
TIL01
10 kΩ
22 kΩ
+
100 µF
10 kΩ
TIL601
THRU
TIL616
680 pF
SN72710
+
−
VCC1
VCC2
GND
OUTPUT
+12 V
10 kΩ
10 kΩ
−6 V

FIGURE 3–OPTICALLY COUPLED AMPLIFIER

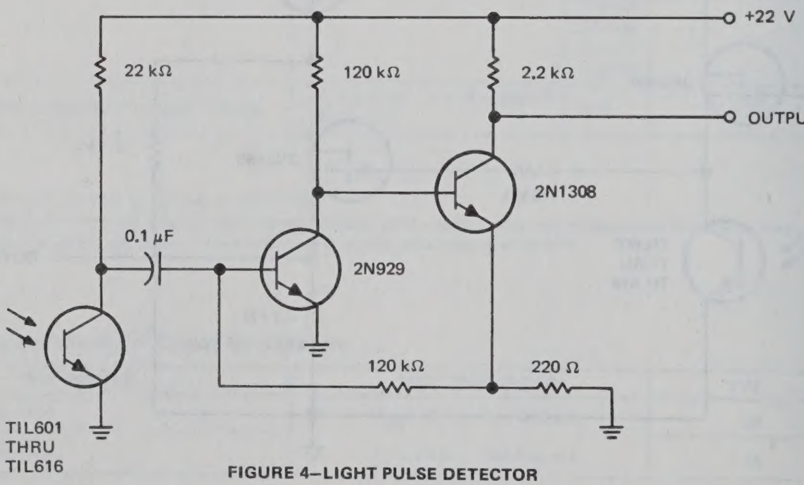

22 kΩ
120 kΩ
2.2 kΩ
+22 V
OUTPUT
2N1308
0.1 µF
2N929
120 kΩ
220 Ω
TIL601
THRU
TIL616

FIGURE 4–LIGHT PULSE DETECTOR

TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

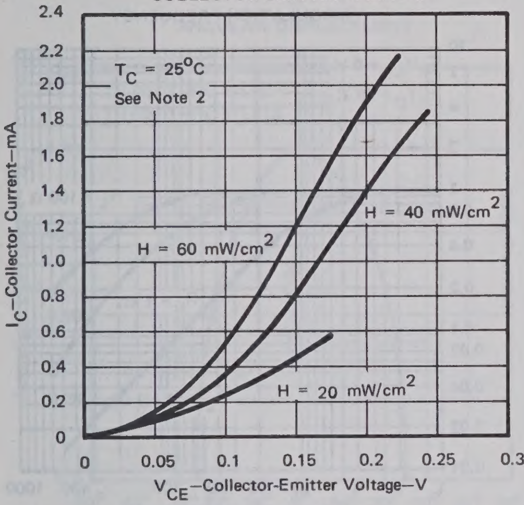


FIGURE 5

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

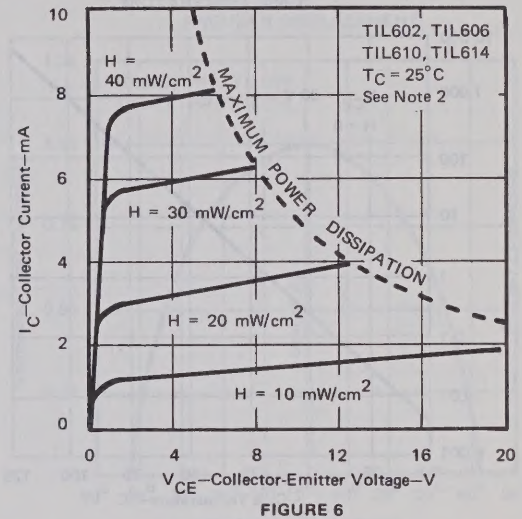


FIGURE 6

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

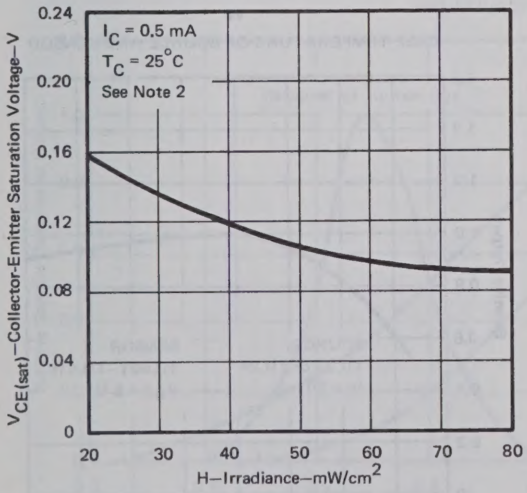


FIGURE 7

COLLECTOR CURRENT
vs
IRRADIANCE

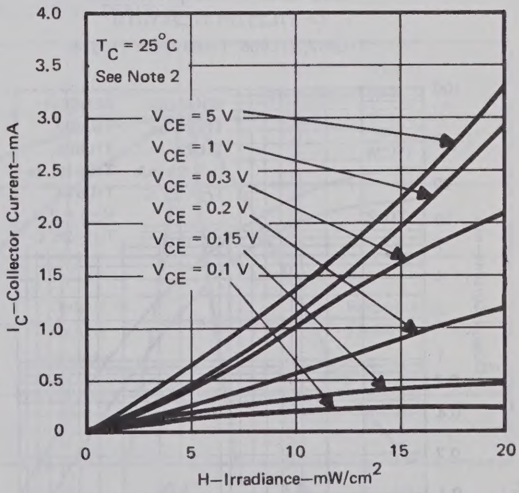


FIGURE 8

NOTE: 2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TYPICAL CHARACTERISTICS

DARK CURRENT
vs
CASE TEMPERATURE

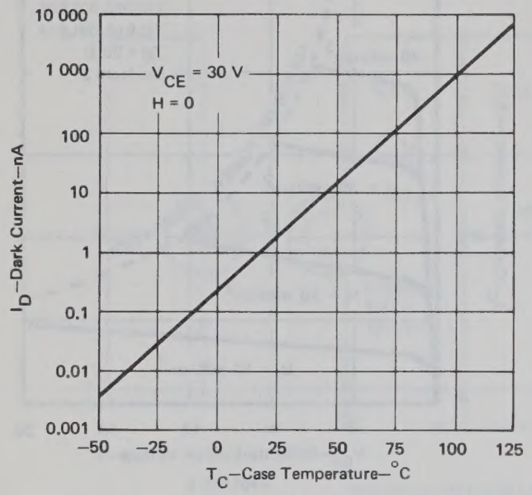


FIGURE 9

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

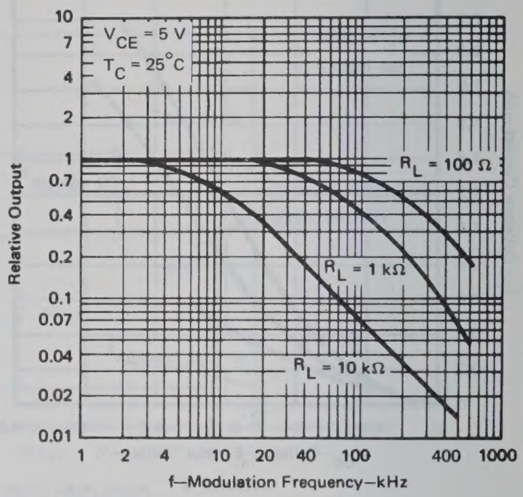


FIGURE 10

COUPLING CHARACTERISTICS
OF TIL23 OR TIL24 WITH
TIL602, TIL606, TIL610, OR TIL614

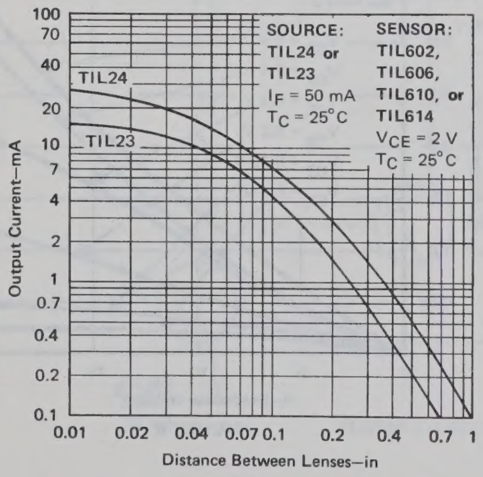


FIGURE 11

RELATIVE OUTPUT
vs
CASE TEMPERATURE OF SOURCE AND SENSOR

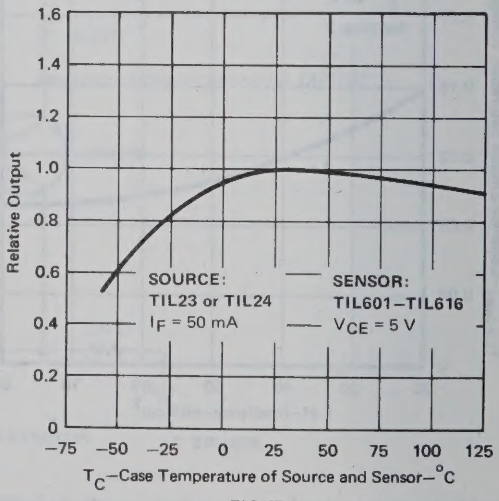


FIGURE 12

TYPICAL CHARACTERISTICS

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

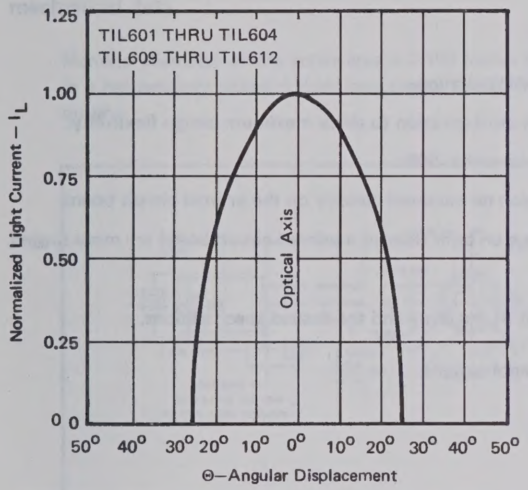


FIGURE 13

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

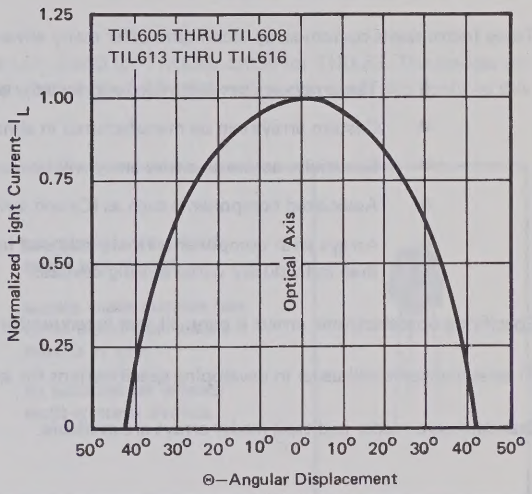


FIGURE 14

RELATIVE SPECTRAL CHARACTERISTICS

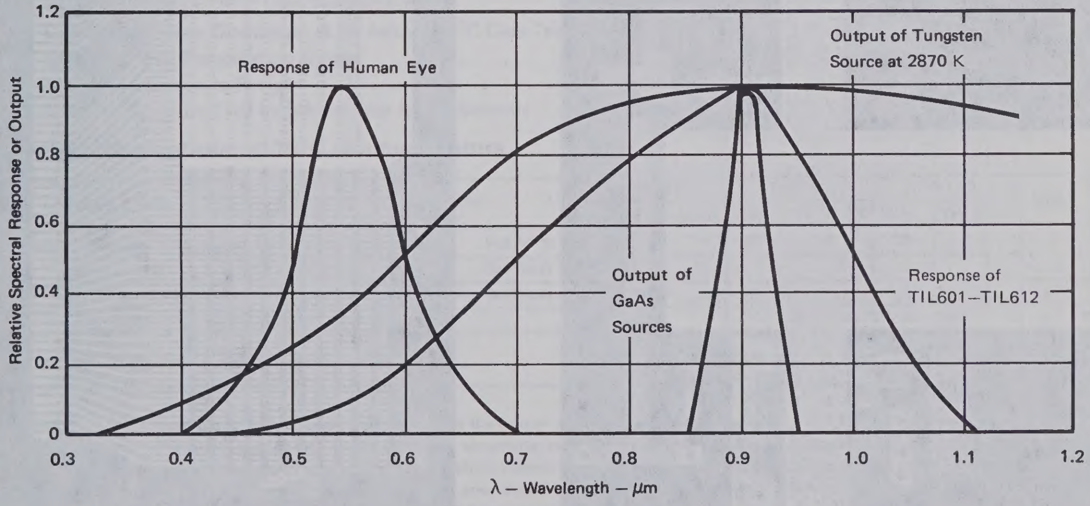


FIGURE 15

TEXAS INSTRUMENTS CUSTOMIZED OPTOELECTRONIC ARRAYS

The TIL601 through TIL616 series is available mounted in printed circuit boards for custom-designed array or matrix applications. The array is a complete unit, without the problems associated with small, difficult-to-handle components. These arrays can be designed for punched-card or tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

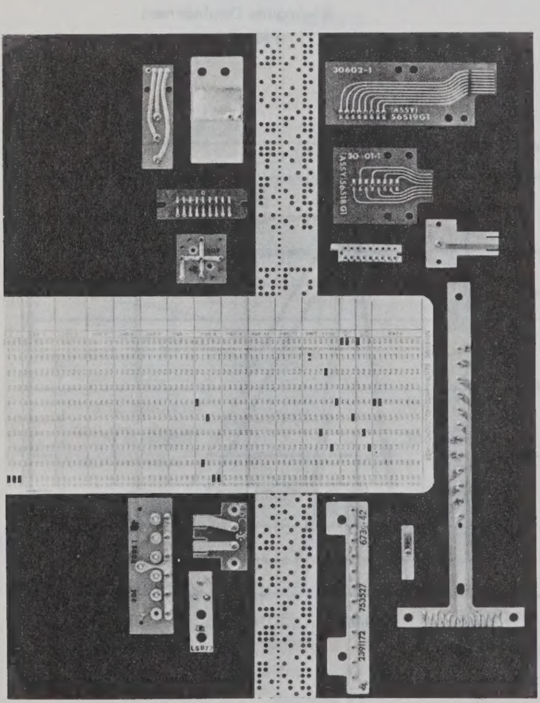
Texas Instruments custom-array techniques offer many advantages:

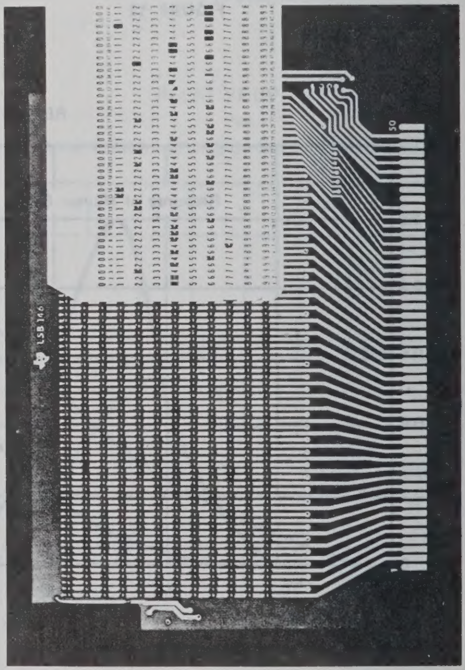
- The arrays are pre-assembled and tested, ready for installation.
- Custom arrays can be manufactured in almost any configuration to allow maximum design flexibility.
- Sensitivity across an entire array will be matched to within 50%.
- Associated components such as ICs and switches can be mounted directly on the printed circuit board.
- Arrays with components firmly soldered into place on both sides of a printed circuit board are more rugged than individually wired sensing devices.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications.

TI sales engineers will assist in developing specifications for special applications.

Standard card-reader and tape-reader arrays are available.





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IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE

TYPES TIXL51, TIXL52, TIXL53
P-N EPITAXIAL PLANAR SILICON LIGHT SENSORS

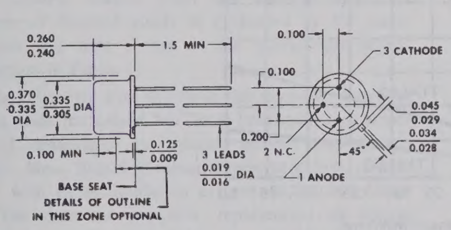
TYPES TIXL51, TIXL52, TIXL53
BULLETIN NO. DL-S 657729, SEPTEMBER 1965

DESIGNED FOR HIGH-SPEED MATRIX COMMUNICATION AND LINE READ-OUT EQUIPMENT

Recommended for Application in Character Recognition, Document Readers, Optical Communications Equipment, and Encoders

mechanical data

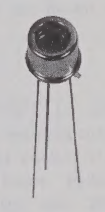
Nominal diameter of the active area is 0.100 inches for TIXL51, 0.050 for TIXL52, 0.030 for TIXL53. The devices are in a hermetically sealed welded case similar to JEDEC TO-5 with window. All TO-5 registration notes also apply to this outline.



THE CATHODE IS IN ELECTRICAL CONTACT WITH THE CASE.

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.010. MINIMUM DIAMETER IS 0.230.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.



absolute maximum ratings

	TIXL51	TIXL52	TIXL53
Reverse Voltage at 25°C Case Temperature	75 V	80 V	100 V
Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW		
Operating Case Temperature Range	−65°C to +125°C		
Storage Temperature Range	−65°C to +150°C		
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C		

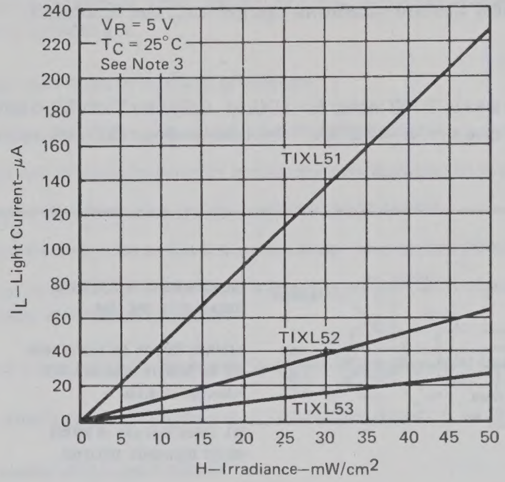
operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS			TIXL51			TIXL52			TIXL53			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)}$	Breakdown Voltage	$I_R = 100\ \mu A$,	$H = 0$,	See Note 2	75			80			100			V
I_D	Dark Current	$V_R = 30$ V,	$H = 0$,	See Note 2			70			50			30	nA
I_L	Light Current	$V_R = 5$ V,	$H = 20\ mW/cm^2$,	See Note 3	60	90		15	25		6	10		μA
C_T	Total Capacitance	$V_R = 30$ V,	$f = 1$ MHz			110			40			24		pF
D★	Detectivity	$V_R = 0$,	See Note 4			8.0×10^{11}			1.3×10^{11}			2.2×10^{10}		$\frac{cm\sqrt{Hz}}{W}$

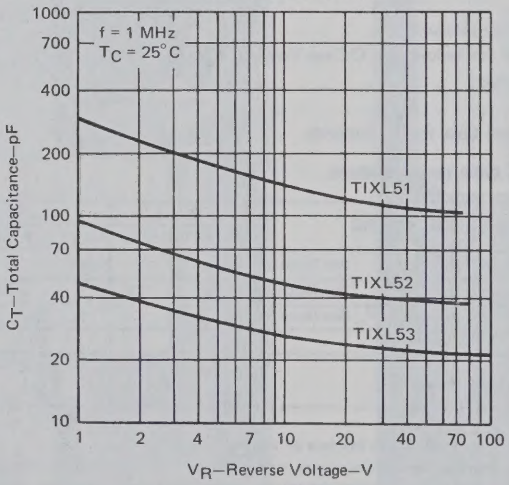
NOTES:
1. Derate linearly to 125°C free-air temperature at the rate of 1 mW/°C.
2. Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.
3. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten-linear-filament bulb operating at 2870 K color temperature.
4. D★ is a chopped irradiance measurement measured using an unfiltered tungsten-filament bulb operating at 2800 K color temperature, chopped at a rate of 1000 Hz, 50% duty cycle, using an amplifier with bandwidth normalized to 1 Hz.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

LIGHT CURRENT
vs
IRRADIANCE



TOTAL CAPACITANCE
vs
REVERSE VOLTAGE



NOTE 3: Irradiance (H) is the radiant per power unit area incident upon a surface. For this measurement the source is an unfiltered tungsten-linear-filament bulb operating at 2870 K color temperature.

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIM
IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE

LS600 RELIABILITY DATA

INTRODUCTION

Texas Instruments designs and builds quality and reliability into all the products which they offer in the electronic marketplace. The Quality Control organization is uniquely responsible for coordinating the total effort and for providing direct action necessary to assure that quality and reliability objectives are met. Accordingly, Quality Control reaches from raw material inputs to evaluation of finished goods as evidenced by the many inspections and tests shown on the typical light sensor flow diagram in Figure 1.

The reliability data shown in this report are based on extensive tests performed by Texas Instruments to assure continued leadership in optical sensor quality and reliability. More than 11,000 units have been subjected to life test with an accumulation of over 10,000,000 device hours. The data are complete, representing all devices produced during the years 1966 through 1969. The tests were performed on un-graded, un-burned-in devices and are typical of TI sensor products. Copies of the data are available through your sales representative.

OPERATING LIFE TESTS

25°C life tests were performed with incident light intensity adjusted for power dissipation on each device of 50 milliwatts at 10 volts V_{CE}. Readings of leakage current (I_D) and light current (I_L) were made at 0, 250, 500 and 1000 hours. Failure criteria were 0.2 μA maximum for I_D and 20% degradation of limits for I_L. A total of 3210 sensors were tested to these criteria with 6 failures. These samples were taken from lots whose total count exceeded 1,050,000 sensors. Data from these tests are shown in Figure 2.

55°C life tests were performed with incident light intensity adjusted for power dissipation on each device of 50 milliwatts at 10 volts V_{CE}. Readings of leakage current (I_D) and light current (I_L) were made at 0, 168 and 1000 hours. Failure criterial were 0.2 μA maximum for I_D and ± 40% change in I_L with original specification limits. A total of 3356 units were tested to these criteria with 11 failures. These samples were taken from lots whose total count exceeded 2,064,000 sensors. Data from these tests are shown in Figure 3.

HIGH TEMPERATURE REVERSE BIAS

Devices are stored in dark oven at 150°C with 45 volts applied for 1000 hours. Readings of leakage current (I_D), breakdown voltage (LV_{CEO}) and light current (I_L) were made at 0, 168 and 1000 hours. Failure criteria were 0.2 μA maximum for I_D and 60% degradation within original limits for I_L. A total of 3320 units were tested to these criteria with 11 failures. These samples were taken from lots whose total count exceeded 2,027,000 sensors. Data from these tests are shown in Figure 4.

STORAGE LIFE TESTS

Devices were stored in ovens at 150°C for 500 and 1000 hours (depending upon requirements). Readings of leakage current (I_D) and light current (I_L) were made at 0, 250, 500 and 1000 hours. Failure criteria were 0.2 μA maximum for I_D and 20% degradation of limits for I_L. A total of 1829 units were tested to these criteria with 6 failures. These samples were taken from lots whose total count exceeded 745,000 sensors. Data from these tests are shown in Figure 5.

The long-term reliability of the LS600 sensor is demonstrated by the plots shown in Figure 6 and Figure 7. The data is completely representative of all tests conducted during the reporting period. The projected degradation limits are based upon the exponential distribution of failure. Extended tests performed on small samples confirm that the degradation is within the limits as shown.

ENVIRONMENTAL TESTS

The tests listed in Figure 8 were performed on samples of the product with no catastrophic or degradation failures observed. It must be pointed out that test conditions shown are not the ultimate strength of the product but represent the test requirements imposed by our customers. The ultimate strength of these devices is much higher in most cases. Inquiries concerning response to particular requirements should be addressed to your TI Sales Representative.

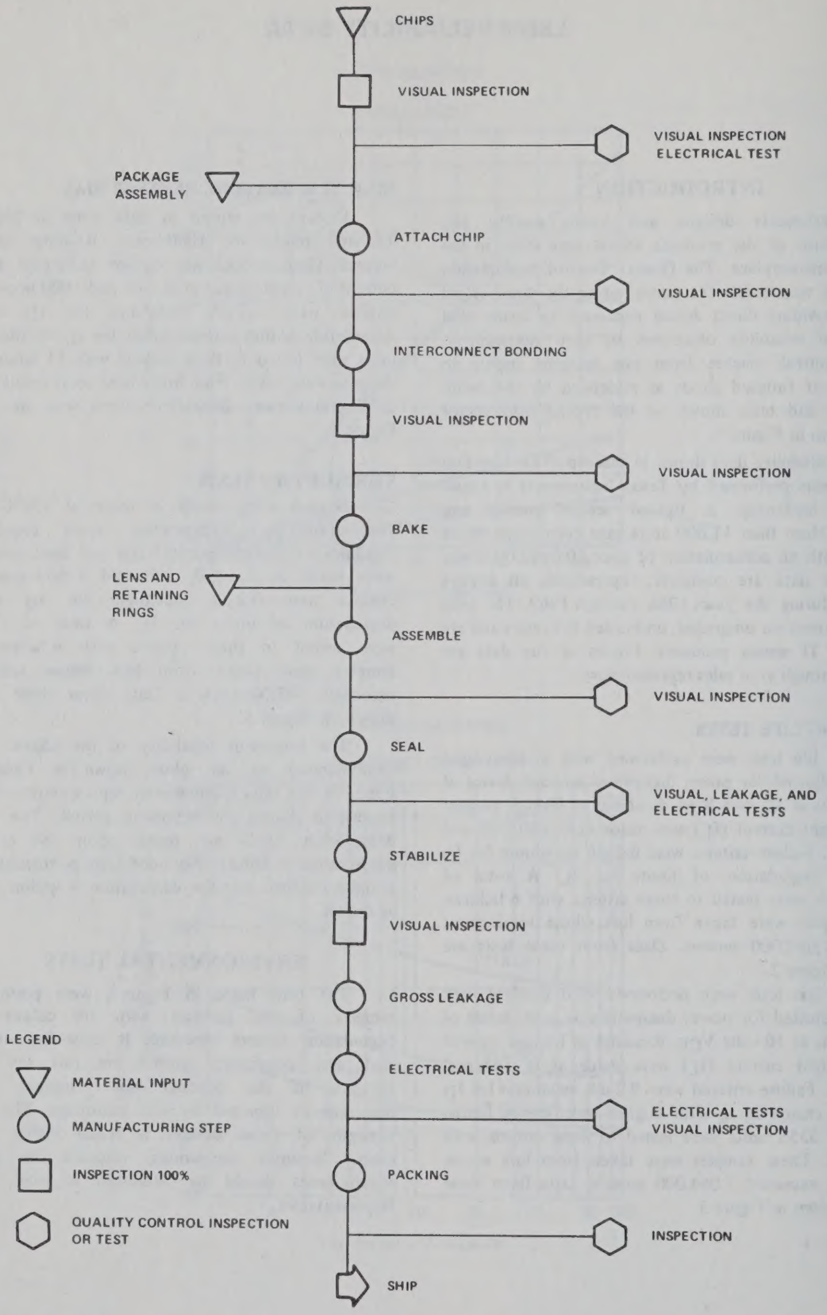
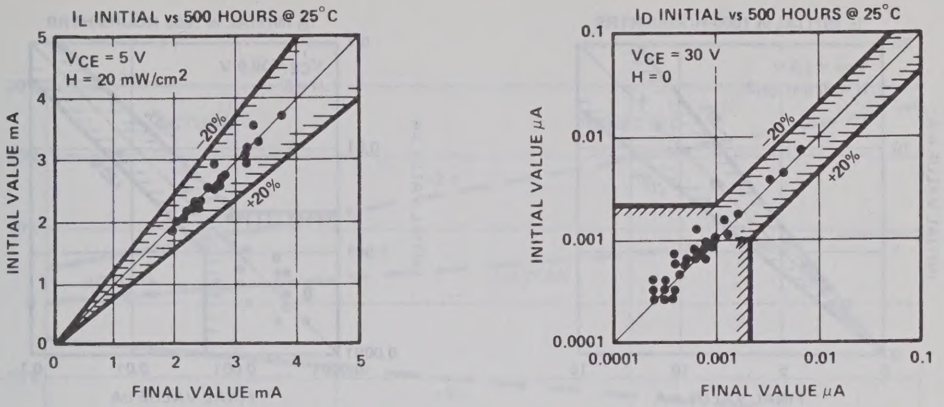
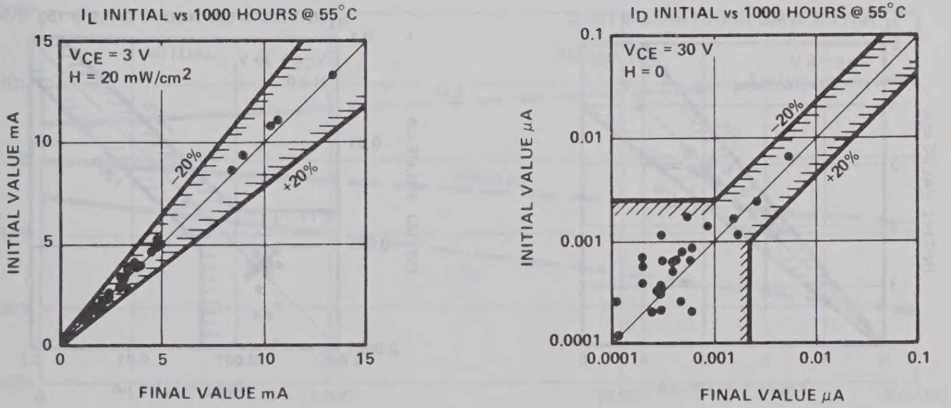

CHIPS
VISUAL INSPECTION
VISUAL INSPECTION
ELECTRICAL TEST
PACKAGE
ASSEMBLY
ATTACH CHIP
VISUAL INSPECTION
INTERCONNECT BONDING
VISUAL INSPECTION
VISUAL INSPECTION
BAKE
LENS AND
RETAINING
RINGS
ASSEMBLE
VISUAL INSPECTION
SEAL
VISUAL, LEAKAGE, AND
ELECTRICAL TESTS
STABILIZE
VISUAL INSPECTION
GROSS LEAKAGE
LEGEND
MATERIAL INPUT
MANUFACTURING STEP
INSPECTION 100%
QUALITY CONTROL INSPECTION
OR TEST
ELECTRICAL TESTS
ELECTRICAL TESTS
VISUAL INSPECTION
PACKING
INSPECTION
SHIP

FIGURE 1. Typical Light Sensor Flow Diagram



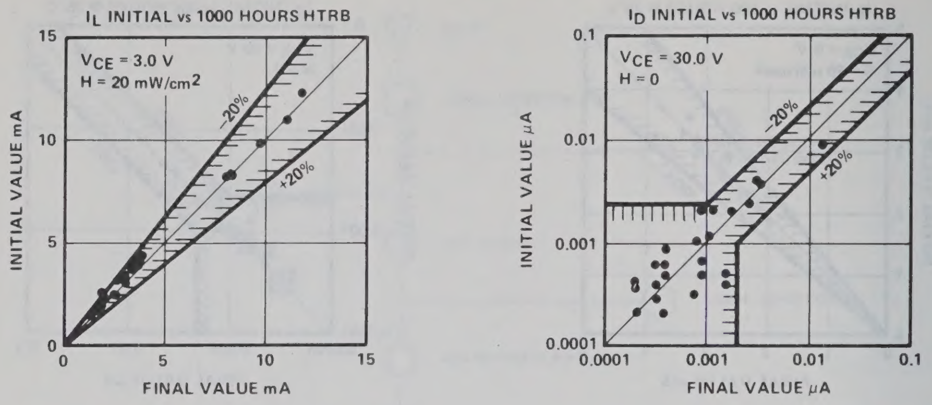
UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN %/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90% CONFIDENCE	
3210	2,847,000	0	6	.20	.33	700,00 HOURS

FIGURE 2. Operating Life at 25°C



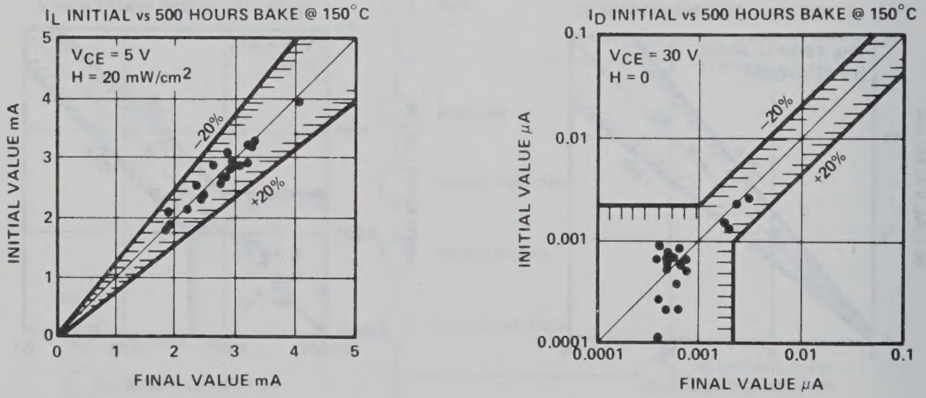
UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN%1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90% CONFIDENCE	
3356	3,356,000	0	11	.36	.49	300,000 HOURS

FIGURE 3. Operating Life at 55°C



UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN %/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90%CONFIDENCE	
3320	3,320,000	0	11	.38	.50	300,000 HOURS

FIGURE 4. High Temperature Reverse Bias



UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN%/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90%CONFIDENCE	
1829	963,500	0	0	.78	1.1	160,000 HOURS

FIGURE 5. High Temperature Storage

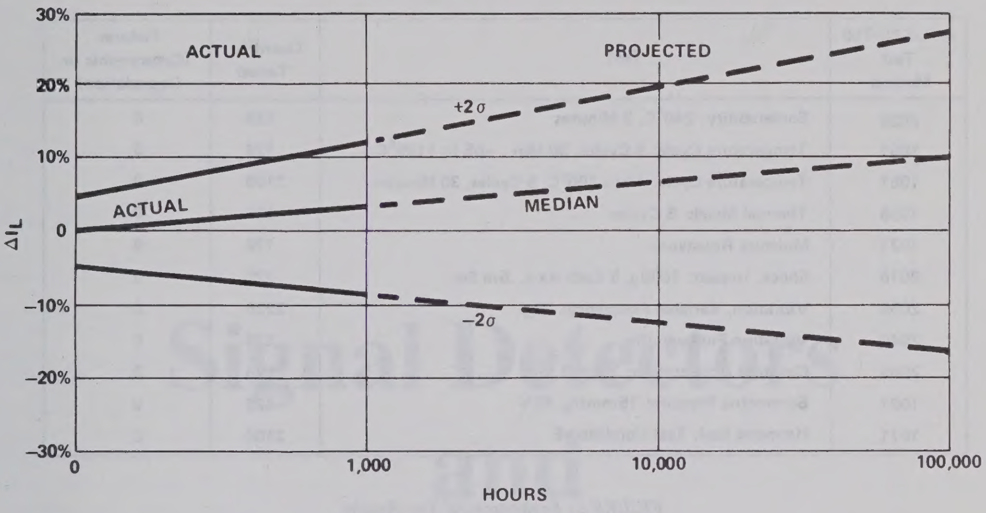


FIGURE 6. % ΔI_L vs Operating Life at 25°C

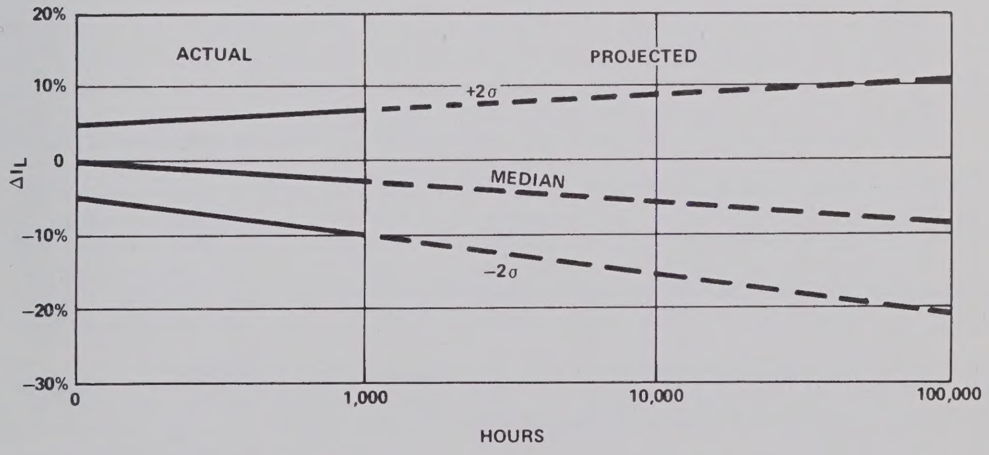


FIGURE 7. % ΔI_L vs Operating Life at 55°C

MIL-STD-750 Test Method	Test	Quantity Tested	Failures (Catastrophic or Degradation)
2026	Solderability: 240°C, 3 Minutes	126	0
1051	Temperature Cycle: 5 Cycles, 30 Min., –65 to +125°C	126	0
1051	Temperature Cycle: 40 to 100°C, 5 Cycles, 30 Minutes	2100	0
1056	Thermal Shock: 5 Cycles	126	0
1021	Moisture Resistance	126	0
2016	Shock, Impact: 1000g, 5 Each Axis, .5m Sec.	126	0
2056	Vibration, Variable Frequency: 10g	2226	0
2046	Vibration Fatigue: 10g	126	0
2006	Constant Acceleration: 10kg, 1 Min.	126	0
1001	Barometric Pressure: 15mmHg, 45 V	126	0
1071	Hermetic Seal: Test Condition E	2100	0

FIGURE 8. Environmental Test Results

Signal Detectors and Amplifiers

QUICK REFERENCE GUIDE
SIGNAL DETECTORS and AMPLIFIERS

SIGNAL DETECTORS
QUICK REFERENCE GUIDE

DEVICE	TYPE	PKG	BREAKDOWN VOLTAGE			AVALANCHE GAIN		C_T TYP	η TYP	FEATURES
			MIN	MAX @	I_R	MIN	TYP			
TIXL55	Avalanche Photodiode	4 C	140 V	200 V	10 μA	100	200	1.2 pF	20% @ 0.63 μm	Si APD, active area 0.01" dia.
TIXL56	Avalanche Photodiode	4 D	140 V	200 V	10 μA	100	200	1.2 pF	20% @ 0.63 μm	Si APD, active area 0.01" dia.
TIXL57	Avalanche Photodiode	4 D	30 V	60 V	100 μA	20	50	4.5 pF	50% @ 1.06 μm	Ge APD, active area 0.01" dia.
TIXL59	Avalanche Photodiode	4 R	140 V	200 V	10 μA	100	200	12 pF	30% @ 0.9 μm	Si APD, active area 0.03" dia.
TIXL68	Avalanche Photodiode	4 D	85 V	150 V	100 μA	15	40	3 pF	25% @ 1.54 μm	Ge APD, active area 0.01" dia.
TIXL69	Avalanche Photodiode	4 R	140 V	200 V	100 μA	50	100	30 pF	40% @ 0.9 μm	Si APD, active area 0.06" dia.
TIXL70	Avalanche Photodetector Head		140 V	200 V	100 μA	100		12 pF	30% @ 0.9 μm	Si APD detector head, contains TIXL59 and reference diode
TIXL71	Avalanche Photodetector Head		30 V	50 V	100 μA	30		10 pF	50% @ 1.06 μm	Ge APD detector head, contains TIXL57, cooler, and reference diode
TIXL72	Avalanche Photodetector Head		85 V	150 V	100 μA	20		5 pF	25% @ 1.54 μm	Ge APD detector head, contains TIXL68, cooler, and reference diode

DEVICE	TYPE	FEATURES
TIXL73	Avalanche Photodetector Module Electronics Section	Contains low-noise, high-speed transimpedance amplifier and bias circuit. Designed for use with TIXL70, TIXL71, and TIXL72 Avalanche Photodetector Heads

DEVICE	TYPE	RESPONSIVITY into 50 Ω TYP	N.E.P. (40 MHz) 1-Hz BANDWIDTH MAX	BANDWIDTH MIN	FEATURES
TIXL74	Avalanche Photodector Module	100 V/mW	5×10^{-13} W/$\sqrt{\text{Hz}}$ @ 0.9 μm	40 MHz	Si APD module. TIXL70 and TIXL73 mated together
TIXL75	Avalanche Photodector Module	28 V/mW	1.5×10^{-12} W/$\sqrt{\text{Hz}}$ @ 1.06 μm	40 MHz	Ge APD module. TIXL71 and TIXL73 mated together
TIXL76	Avalanche Photodector Module	10 V/mW	6×10^{-12} W/$\sqrt{\text{Hz}}$ @ 1.54 μm	40 MHz	Ge APD module. TIXL72 and TIXL73 mated together
TIXL79	Avalanche Photodetector Module	100 V/mW	5×10^{-13} W/$\sqrt{\text{Hz}}$ @ 0.9 μm	40 MHz	Si APD module. Low-Profile. For 0.9 μm to 1.06 μm operation

DEVICE	TYPE	PKG	BREAKDOWN VOLTAGE MIN	RESPONSIVITY TYP	C_T TYP	RISE TIME TYP	FEATURES
TIXL80	Photodiode	5 M	200 V @ I_R = 100 μA	0.55 A/W @ 0.9 μm	5 pF	15 ns	Large Area Si Photodiode

DEVICE	TYPE	PKG	EQUIVALENT INPUT NOISE CURRENT	Z_I TYP	Z_O TYP	Z_F TYP	BANDWIDTH TYP	FEATURES
TIXL151	Amplifier	5 T	4.5 pA/$\sqrt{\text{Hz}}$ TYP	100 Ω	2 Ω	4 kΩ	50 MHz	Low-noise, high-speed amplifiers designed for use with photodiodes
TIXL152	Amplifier	5 T	3 pA/$\sqrt{\text{Hz}}$ TYP	300 Ω	4 Ω	12 kΩ	18 MHz	

SIGNAL DETECTORS AND AMPLIFIERS

Signal detectors are that class of photodetectors designed for detection of weak optical signals at visible or near-infrared wavelengths in receiver-type applications such as rangefinders, distance meters, and optical communications. Basically they are of the same construction as any junction photodiode such as those used for card readers; however, they are optimized for high quantum efficiency, low noise, and high speed.

The products included in this section are:

- Photodiodes
- Avalanche Photodiodes
- Low-Noise Amplifiers
- Photodetector Modules

In addition, Texas Instruments produces a broad range of custom detectors of various geometries including arrays and quadrants. Inquiries on custom detectors are invited.

The photodiodes in this class of product are generally made from high-resistivity silicon; however, low-resistivity silicon or germanium is sometimes used depending on the application. The TIXL80 is an example of the performance available using high-resistivity silicon. Texas Instruments Bulletin CB-121, "Silicon *Photoamperic*† Detectors", provides additional information on this type of detector.

The avalanche photodiode (APD) is a photodiode especially suited for low-noise applications where the principal noise source is the preamplifier. An APD has characteristics similiar to a conventional photodiode with the addition of an internal linear current-gain mechanism due to the avalanche effect. The gain is determined by applied reverse bias just below the breakdown voltage of the diode. The gain, M, is controllable from 1 to the minimum value specified in the data sheet.

Signal current gain in the photodiode improves the sensitivity of the system by a factor which varies from equal to the gain up to the point where the noise caused by the bulk reverse current of the photodiode is comparable to that of the amplifier. This noise can be determined by multiplying the square of the shot noise current by the avalanche gain raised to the power given in the data sheet. See Figure 1 of the data sheets for types TIXL55, TIXL57, TIXL59, TIXL68, or TIXL69. This exponent is typically 2.3 and 3.0 for silicon and germanium APD's respectively.

Amplifiers used with photodiodes are of particular importance in determining system sensitivity. A photodiode is in effect a current source and the amplifier input should be designed for such a signal while introducing low noise current, itself. The output is normally a low-impedance voltage source. For frequency responses up to 10 MHz, an operational amplifier operated in the transimpedance mode is generally recommended. For frequencies above this, Texas Instruments provides the TIXL151 and TIXL152 transimpedance amplifiers with 40-MHz and 12-MHz bandwidths, respectively. Microwave photodetector systems normally use available standard low-noise 50-ohm-input amplifiers.

Photodetector modules are complete optical receiver assemblies. Those listed in this section contain a sensitive APD and a low-noise transimpedance amplifier. In addition they also contain an automatic bias circuit for constant-gain operation of the APD over a range of temperatures. These modules allow the incorporation of the sensitive APD's into systems with a minimum of cost.

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†Trademark of Texas Instruments Incorporated

TYPES TIXL55, TIXL56
SILICON AVALANCHE PHOTODIODES

- **Useful from audio to microwave frequencies**
- **Typical photocurrent gain of 200**
- **Active area of 5x10^{-4} cm^2**
- **Typical gain-bandwidth product† of 80 GHz**
- **Typical system noise equivalent power of 10^{-12} W/$\sqrt{\text{Hz}}$ at 1 GHz**
- **Pill-package design allows mounting in coaxial and stripline microwave structures**

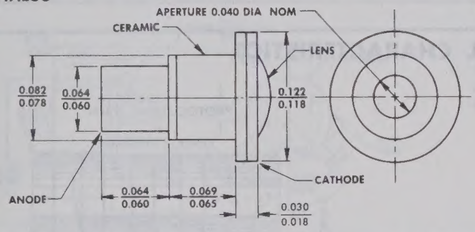
description

The TIXL55 and TIXL56 are high-speed photodiodes used for engineering evaluation and designed to operate in the avalanche breakdown region. Photocurrent gain results from avalanche multiplication and provides excellent low noise performance over wide bandwidths.

mechanical data

The devices are in hermetically sealed packages with glass window. The outline of the TIXL56 is similar to TO-18 except for the window. All TO-18 registration notes also apply to this outline.

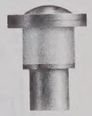
TIXL55


APERTURE 0.040 DIA NOM
CERAMIC
LENS
0.082/0.078
0.064/0.060
0.122/0.118
CATHODE
ANODE
0.064/0.060
0.069/0.065
0.030/0.018

THE LENS IS CORNING 7052 (OR EQUIVALENT) GLASS. ITS FOCAL LENGTH IS 0.110 REFERENCED TO THE TOP OF THE FLANGE.

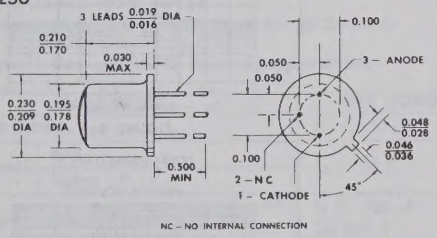
THE ACTIVE SURFACE IS 0.035 BELOW THE TOP OF THE FLANGE. ITS DIAMETER IS 0.010.

ALL DIMENSIONS ARE IN INCHES



4 TIMES ACTUAL SIZE

TIXL56


3 LEADS 0.019/0.016 DIA
0.210/0.170
0.030 MAX
0.230/0.209 DIA
0.195/0.178 DIA
0.500 MIN
0.100
0.050
0.050
3 – ANODE
0.048/0.028
0.046/0.036
0.100
2 – NC
1 – CATHODE
45°
NC – NO INTERNAL CONNECTION

THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE.

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.040, MINIMUM DIAMETER IS 0.125

THE LENS IS CORNING 7052 (OR EQUIVALENT) GLASS.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1) . . . . . . 100 mW
Operating Temperature Range . . . . –65°C to 125°C
Soldering Temperature for 3 Minutes (TIXL55) . . . . 240°C
Lead Temperature ⅟₁₆ Inch from Case for 10 Seconds (TIXL56) . . . . 300°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mW/deg.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TYPES TIXL55, TIXL56
SILICON AVALANCHE PHOTODIODES

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		$I_R = 10\ \mu A$, $H = 0$	140	170	200	V
Dark Current‡	Bulk	$V_R = 100$ V, $H = 0$		0.5	2	nA
	Surface			10		
Temperature Coefficient of Breakdown Voltage		$I_R = 10\ \mu A$, $H = 0$, See Note 2		190		mV/deg
Photocurrent Gain at Sustained Avalanche Noise Threshold, M_T		See Note 3	100	200		
Total Capacitance, C_T		$V_R = 100$ V, $f = 1$ MHz		1.2	3	pF
Series Resistance		$f = 0.9$ GHz		50		Ω
Gain-Bandwidth Product†		$f = 1$ GHz, $\lambda = 6328$ Å		80		GHz
Quantum Efficiency		$\lambda = 6328$ Å, $M = 100$		20%		

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark current is the sum of surface current and gain M times the bulk current.

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125°C - V_{(BR)} @ -55°C}{125°C - (-55°C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See figure 1. Light intensity is as required to give a photocurrent of 1 nA at $V_R = 100$ V.

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER vs PHOTOCURRENT GAIN

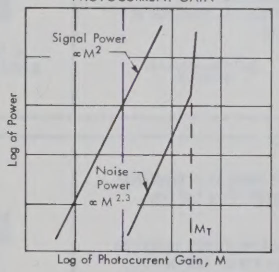


FIGURE 1

PHOTOCURRENT GAIN vs REVERSE VOLTAGE

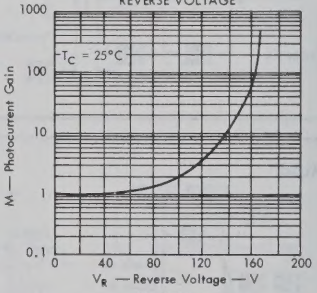


FIGURE 2

RELATIVE QUANTUM EFFICIENCY vs WAVELENGTH

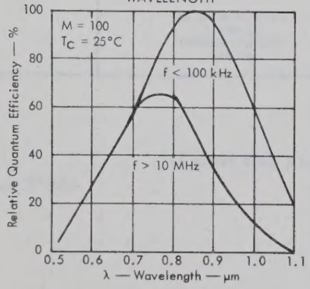


FIGURE 3

TOTAL CAPACITANCE vs REVERSE VOLTAGE

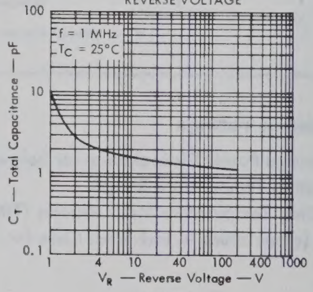


FIGURE 4

BIBLIOGRAPHY: Biard, J. R. and W. N. Shaunfield: A Model of the Avalanche Photodiode, *IEEE Transactions on Electron Devices*, vol. ED-14, no. 5, pp. 233-238, May, 1967.

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TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

TYPE TIXL57
GERMANIUM AVALANCHE PHOTODIODE

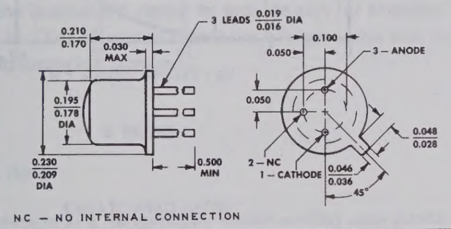
- **Optimized for near-infrared lasers**
- **Typical photocurrent gain of 50**
- **Active area of 5 x 10^{-4} cm^2**
- **Useful from audio to microwave frequencies**
- **Typical gain-bandwidth product† of 50 GHz**
- **Typical system noise equivalent power of 10^{-12} W/$\sqrt{\text{Hz}}$ at 30-MHz bandwidth**

description

The TIXL57 is an experimental high-speed photodiode used for engineering evaluation and designed to operate in the avalanche breakdown region. Photocurrent gain results from avalanche multiplication and provides excellent low-noise performance over wide bandwidths.

mechanical data

The device is in a hermetically sealed welded case similar to JEDEC TO-18 with window. All TO-18 registration notes also apply to this outline. Approximate weight is 0.35 gram.


3 LEADS $\frac{0.019}{0.016}$ DIA
$\frac{0.210}{0.170}$
$\frac{0.030}{\text{MAX}}$
$\frac{0.195}{0.178}$ DIA
$\frac{0.230}{0.209}$ DIA
0.500 MIN
0.100
0.050
3 — ANODE
0.050
$\frac{0.048}{0.028}$
2 — NC
1 — CATHODE
$\frac{0.046}{0.036}$
45°
NC — NO INTERNAL CONNECTION

THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE.

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.040, MINIMUM DIAMETER IS 0.125

THE LENS IS CORNING 7052 (OR EQUIVALENT) GLASS.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Temperature Range	–65°C to 125°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		$I_R = 100\ \mu A$, $H = 0$	30	40	60	V
Dark Current‡	Bulk	$V_R = 15$ V, $H = 0$		0.2	1	μA
	Surface			5		
Temperature Coefficient of Breakdown Voltage		$I_R = 100\ \mu A$, $H = 0$, See Note 2		60		mV/deg
Photocurrent Gain at Sustained Avalanche Noise Threshold, M_T		See Note 3	20	50		
Total Capacitance, C_T		$V_R = 30$ V, $f = 1$ MHz		4.5	7	pF
Series Resistance		f = 0.9 GHz		20		Ω
Quantum Efficiency		$\lambda = 1.4\ \mu m$		60%		

NOTES: 1. Derate linearly to 125°C case temperature at the rate of 1 mW/deg.

2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @125°C - V_{(BR)} @-55°C}{125°C - (-55°C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See figure 1. Light intensity is as required to give a photocurrent of 0.1 μA at $V_R = 15$ V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark current is the sum of surface current and gain M times the bulk current.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TYPE TIXL57
GERMANIUM AVALANCHE PHOTODIODE

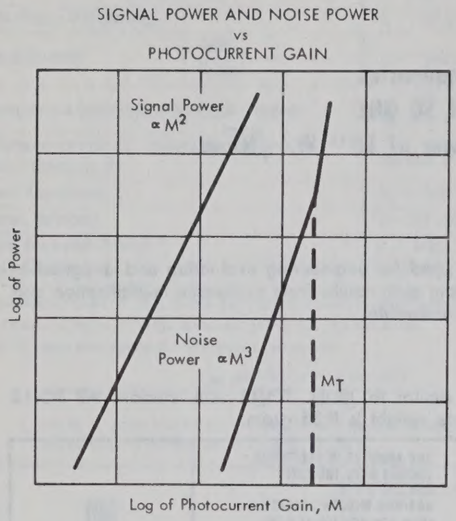

SIGNAL POWER AND NOISE POWER vs PHOTOCURRENT GAIN

FIGURE 1

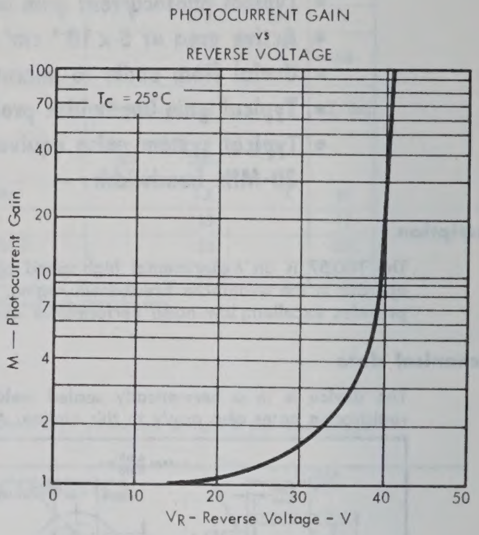

PHOTOCURRENT GAIN vs REVERSE VOLTAGE

FIGURE 2

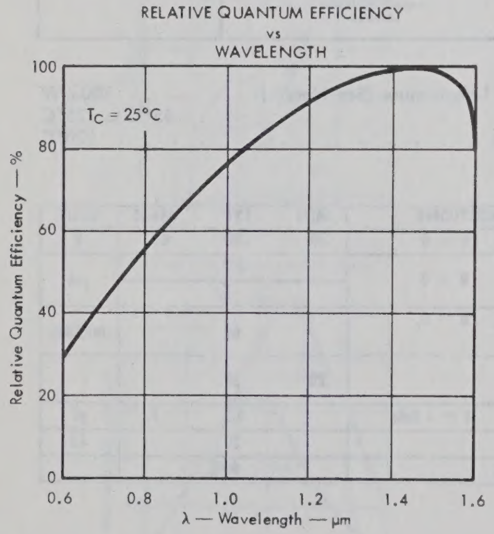

RELATIVE QUANTUM EFFICIENCY vs WAVELENGTH

FIGURE 3

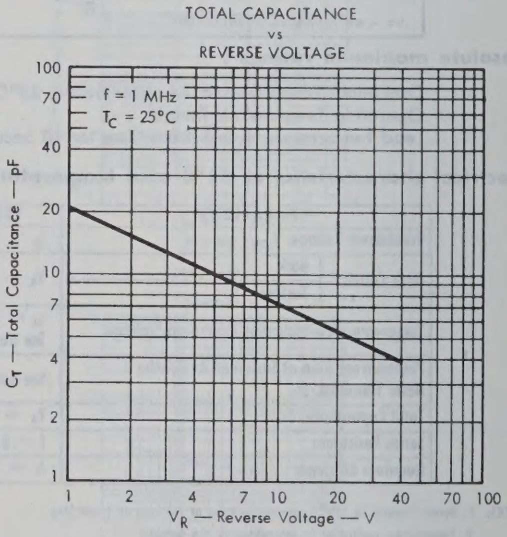

TOTAL CAPACITANCE vs REVERSE VOLTAGE

FIGURE 4

BIBLIOGRAPHY: Biard, J. R. and W. N. Shaunfield, A Model of the Avalanche Photodiode, *IEEE Transactions on Electron Devices*, Vol. ED-14, no. 5, pp. 233-238, May, 1967.

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IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE

TYPE TIXL59
SILICON AVALANCHE PHOTODIODE

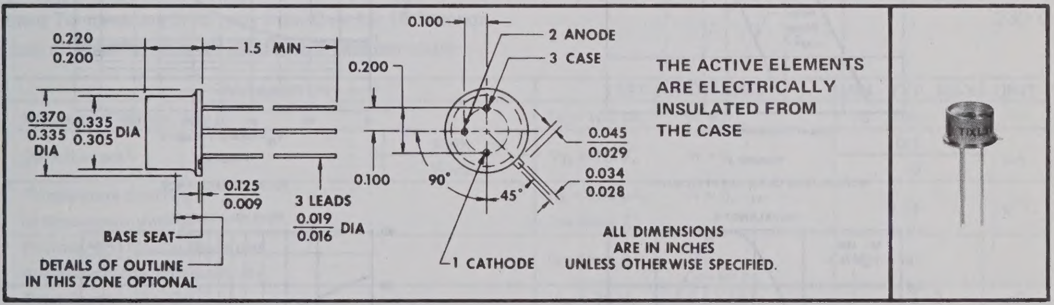
- Optimized for Near-Infrared Lasers
- Isolated Case for Shielding
- Useful from Audio to Microwave Frequencies
- Typical Photocurrent Gain of 100
- Active Area of 4.5×10^{-3} cm^2 (Diameter = 0.030 in)
- Typical Gain-Bandwidth Product† of 80 GHz
- Typical System Noise Equivalent Power of 2×10^{-13} W/$\sqrt{\text{Hz}}$ at 30-MHz Bandwidth

description

The TIXL59 is a high-speed photodiode intended for engineering evaluation. This device is designed to operate in the avalanche breakdown region to provide gain for excellent low-noise performance over wide bandwidths. The TIXL59 is similar to TIXL56 except that it has a larger active area making it more useful in lens systems with smaller f-numbers or where focusing is a problem.

mechanical data

The device is in a hermetically sealed welded case similar to, but slightly shorter than, JEDEC TO-5 with window. All TO-5 registration notes also apply to this outline. The lens is borosilicate glass. Its nominal dimensions are: diameter, 0.305 inch; thickness, 0.060 inch; and distance from front surface of the lens to the active area, 0.085 inch.


0.220
0.200
1.5 MIN
0.370
0.335
DIA
0.335
0.305
DIA
0.125
0.009
BASE SEAT
DETAILS OF OUTLINE IN THIS ZONE OPTIONAL
3 LEADS
0.019
0.016
DIA
0.100
0.200
0.100
90°
45°
2 ANODE
3 CASE
0.045
0.029
0.034
0.028
1 CATHODE
THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE
ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TIXL

absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	–65°C to 125°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTE: 1. Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		$I_R = 10\ \mu A$, H = 0	140	170	200	V
Dark Current‡	Bulk	$V_R = 100$ V, H = 0		20	150	pA
	Surface			10		nA
Temperature Coefficient of Breakdown Voltage		$I_R = 10\ \mu A$, H = 0, See Note 2		190		mV/°C
Photocurrent Gain at Sustained Avalanche Noise Threshold, M_T		See Note 3	100	200		
Total Capacitance, C_T		$V_R = 100$ V, f = 1 MHz		8.5	12	pF
Series Resistance		f = 0.9 GHz		5		Ω
Gain-Bandwidth Product†		f = 1 GHz, λ = 6328 Å		80		GHz
Quantum Efficiency		λ = 7000 Å, M = 100		35%		

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125^\circ C - V_{(BR)} @ -55^\circ C}{125\ ^\circ C - (-55^\circ C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Light intensity is as required to give a photocurrent of 1 nA at $V_R = 100$ V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark current is the sum of surface current and gain M times the bulk current.

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER
vs
PHOTOCURRENT GAIN

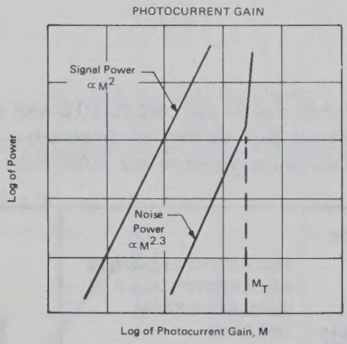


FIGURE 1

PHOTOCURRENT GAIN
vs
REVERSE VOLTAGE

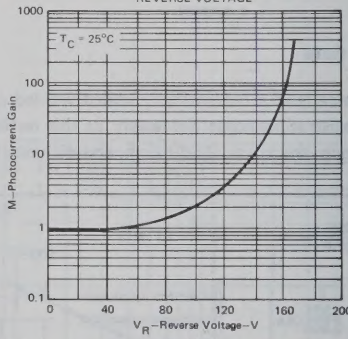


FIGURE 2

NORMALIZED QUANTUM EFFICIENCY
vs
WAVELENGTH

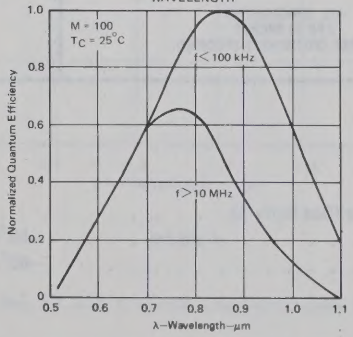


FIGURE 3

TOTAL CAPACITANCE
vs
REVERSE VOLTAGE

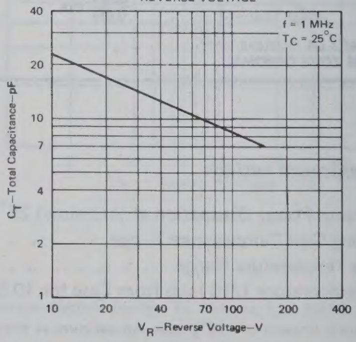


FIGURE 4

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TYPE TIXL68
GERMANIUM AVALANCHE PHOTODIODE

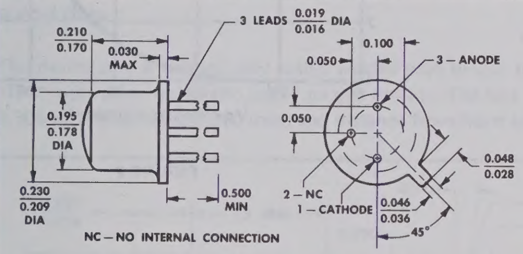
- Useful from Audio to Microwave Frequencies
- Typical Photocurrent Gain of 45
- Active Area of 5 X 10^{-4} cm^2 (Dia. = 0.010″)
- Typical Gain-Bandwidth Product† of 50 GHz
- Typical System Noise Equivalent Power of 5 X 10^{-12} W/$\sqrt{\text{Hz}}$ at 40-MHz Bandwidth with TIXL151 Amplifier

description

The TIXL68 is a high-speed photodiode available for engineering evaluation. This device is designed to operate near avalanche breakdown to provide gain for excellent low-noise performance over wide bandwidths. The TIXL68 is similar to the TIXL57 except that it has a higher breakdown, allowing higher quantum efficiency to be achieved for 1.54 μm detection. In addition, an anti-reflection coating for 1.54 μm is applied.

mechanical data

The device is in a hermetically sealed welded case similar to JEDEC TO-18 with window. All TO-18 registration notes also apply to this outline. Approximate weight is 0.35 gram.



THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.040, MINIMUM DIAMETER IS 0.125

THE LENS IS CORNING 7052 (OR EQUIVALENT) GLASS

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1) . . . . 100 mW
Operating Temperature Range . . . . −65°C to 100°C
Storage Temperature Range . . . . −65°C to 100°C
Lead Temperature 1/16 Inch from Case for 10 Seconds . . . . 230°C

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		I_R = 100 μA, H = 0	85	100	150	V
Dark Current‡	Bulk	V_R = 15 V, H = 0		0.4	0.8	μA
	Surface			8		
Temperature Coefficient of Breakdown Voltage		I_R = 100 μA, H = 0, See Note 2		0.14		%/°C
Photocurrent Gain at Sustained Avalanche Noise Threshold, M_T		See Note 3	15	40		
Total Capacitance, C_T		V_R = 30 V, f = 1 MHz		3		pF
Series Resistance		f = 0.9 GHz		25		Ω
Gain-Bandwidth Product†		f = 1 GHz, λ = 1.15 μm		50		GHz
Quantum Efficiency		λ = 1.54 μm, f > 10 MHz		25 %		

NOTES: 1. Derate linearly to 100°C case temperature at the rate of 1.33 mW/°C.

2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \left[\frac{V_{(BR)}\ @\ 100^\circ\text{C} - V_{(BR)}\ @\ -65^\circ\text{C}}{V_{(BR)}\ @\ 25^\circ\text{C}}\right]\frac{100\%}{165^\circ\text{C}}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Light intensity is as required to give a photocurrent of 0.1 μA at V_R = 15 V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark current is the sum of surface current and gain M times the bulk current.

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

TYPE TIXL68
GERMANIUM AVALANCHE PHOTODIODE

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER
vs
PHOTOCURRENT GAIN

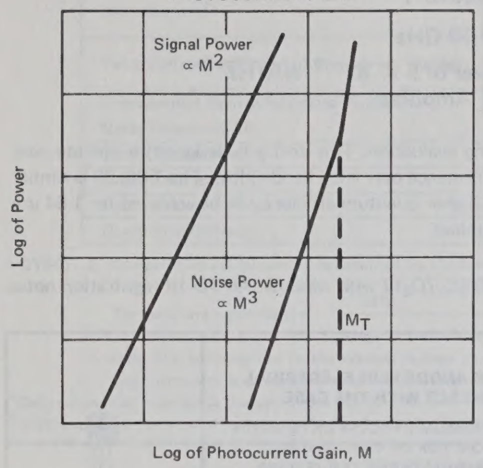


FIGURE 1

PHOTOCURRENT GAIN
vs
REVERSE VOLTAGE

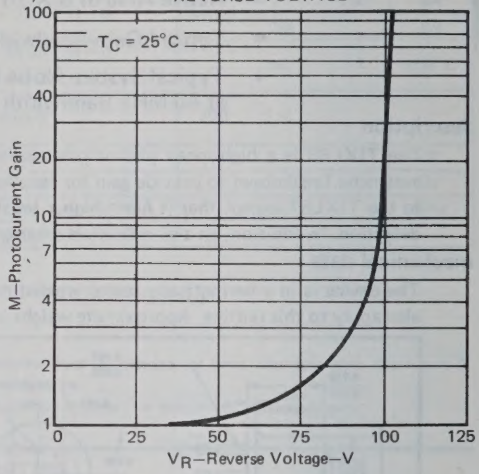


FIGURE 2

NORMALIZED QUANTUM EFFICIENCY
vs
WAVELENGTH

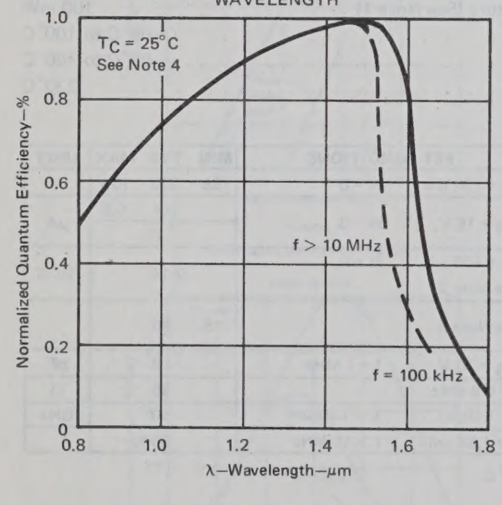


FIGURE 3

TOTAL CAPACITANCE
vs
REVERSE VOLTAGE

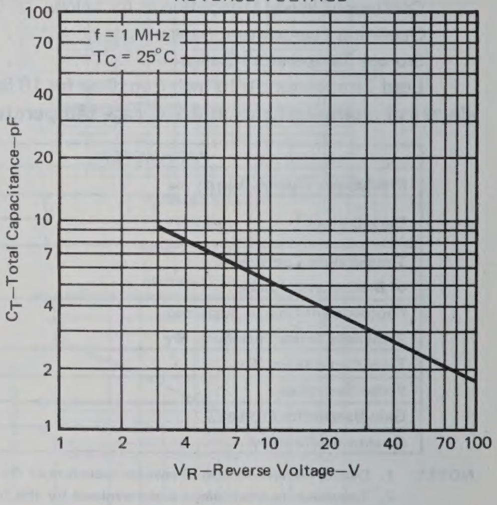


FIGURE 4

NOTE 4: Dashed line is an extrapolation necessary because of test-equipment limitations.

BIBLIOGRAPHY: Biard, J. R. and W. N. Shaunfield, A Model of the Avalanche Photodiode, *IEEE Transactions on Electron Devices,* no. 5, pp. 233-238, May, 1967.

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TYPE TIXL69
LARGE-AREA SILICON AVALANCHE PHOTODIODE

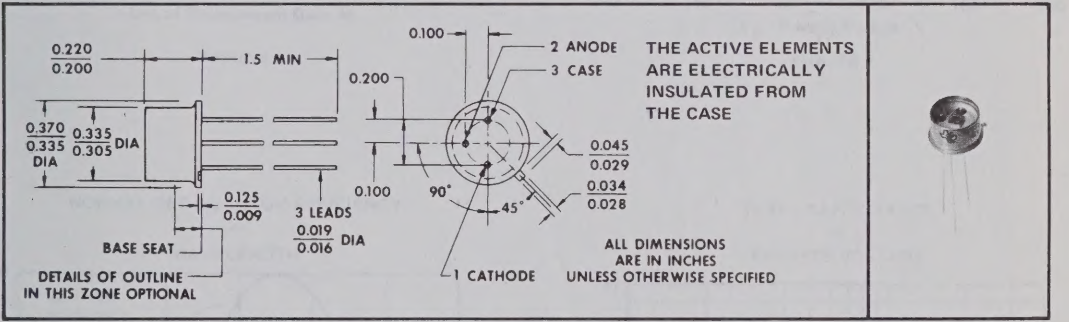
- Useful from Audio to Microwave Frequencies
- Typical Photocurrent Gain of 100
- Active Area of 1.8 X 10^{-2} cm^2 (Dia. = 0.060")
- Typical Gain-Bandwidth Product† of 80 GHz
- Typical System Noise Equivalent Power of 2 X 10^{-13} $W/\sqrt{Hz}$ at 30-MHz Bandwidth with TIXL151 Amplifier

description

The TIXL69 is a high-speed photodiode available for engineering evaluation. This device is designed to operate in the avalanche breakdown region to provide gain for excellent low-noise performance over wide bandwidths. The TIXL69 is similar to the TIXL56 and TIXL59 except that it has a larger active area. The operating case temperature range is –65°C to 125°C.

mechanical data

The device is in a hermetically sealed welded case similar to, but slightly shorter than, JEDEC TO-5 with window. All TO-5 registration notes also apply to this outline. The lens is borosilicate glass. Nominal lens dimensions are: diameter, 0.305 inch; thickness, 0.060 inch; and distance from front surface of the lens to the active area, 0.075 inch.


0.220
0.200
1.5 MIN
0.370
0.335
DIA
0.335
0.305
DIA
0.125
0.009
BASE SEAT
DETAILS OF OUTLINE IN THIS ZONE OPTIONAL
3 LEADS
0.019
0.016
DIA
0.100
0.200
0.100
90°
45°
2 ANODE
3 CASE
1 CATHODE
0.045
0.029
0.034
0.028
THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE
ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	–65°C to 125°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

TENTATIVE DATA SHEET

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS§		MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		I_R = 100 μA,	H = 0	140	170	200	V
Dark Current‡	Bulk	V_R = 100 V,	H = 0		140	700	pA
	Surface	V_R = 100 V,	H = 0		40		nA
Temperature Coefficient of Breakdown Voltage		I_R = 100 μA, H = 0, See Note 2			0.11		%/°C
Photocurrent Gain at Sustained Avalanche Noise Threshold, M_T		See Note 3		50	100		
Total Capacitance, C_T		V_R = 100 V,	f = 1 MHz		30		pF
Series Resistance, R_S		f = 0.9 GHz			5		Ω
Gain-Bandwidth Product†		f = 1 GHz,	λ = 6328 Å		80		GHz
Quantum Efficiency		λ = 9000 Å,	f > 10 MHz		40%		

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \left[\frac{V_{(BR)}\ @\ 125^\circ\text{C} - V_{(BR)}\ @\ -55^\circ\text{C}}{V_{(BR)}\ @\ 25^\circ\text{C}}\right]\frac{100\%}{180^\circ\text{C}}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Light intensity is as required to give a photocurrent of 1 nA at V_R = 100 V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark Current is the sum of surface current and gain M times the bulk current.

§H is the incident radiant power per unit active area.

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER
vs
PHOTOCURRENT GAIN

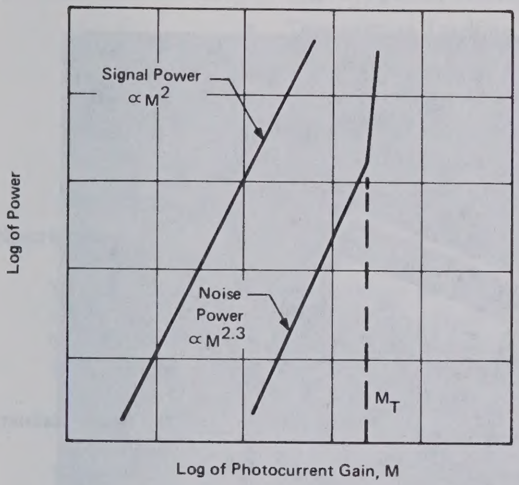


FIGURE 1

PHOTOCURRENT GAIN
vs
REVERSE VOLTAGE

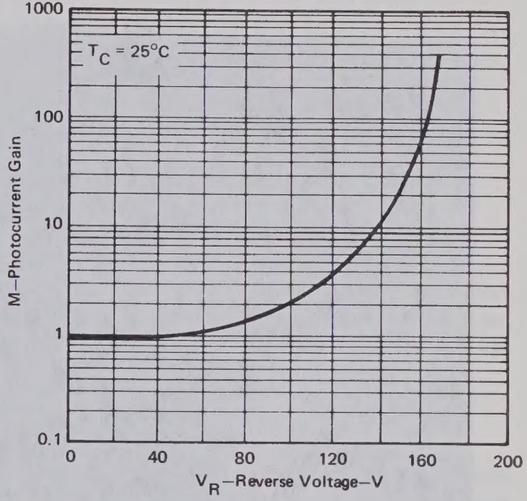


FIGURE 2

NORMALIZED QUANTUM EFFICIENCY
vs
WAVELENGTH

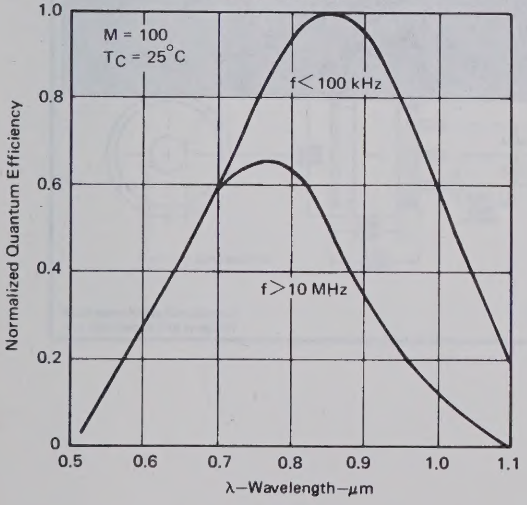


FIGURE 3

TOTAL CAPACITANCE
vs
REVERSE VOLTAGE

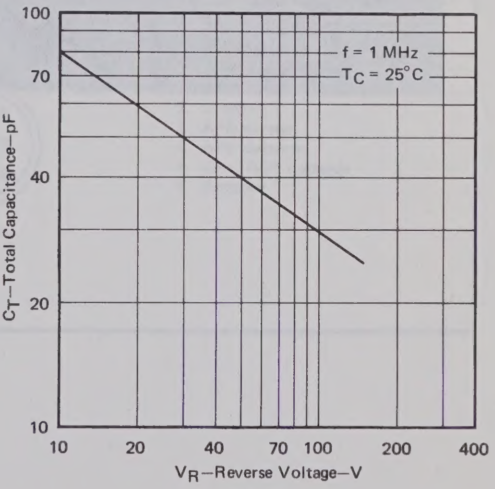


FIGURE 4

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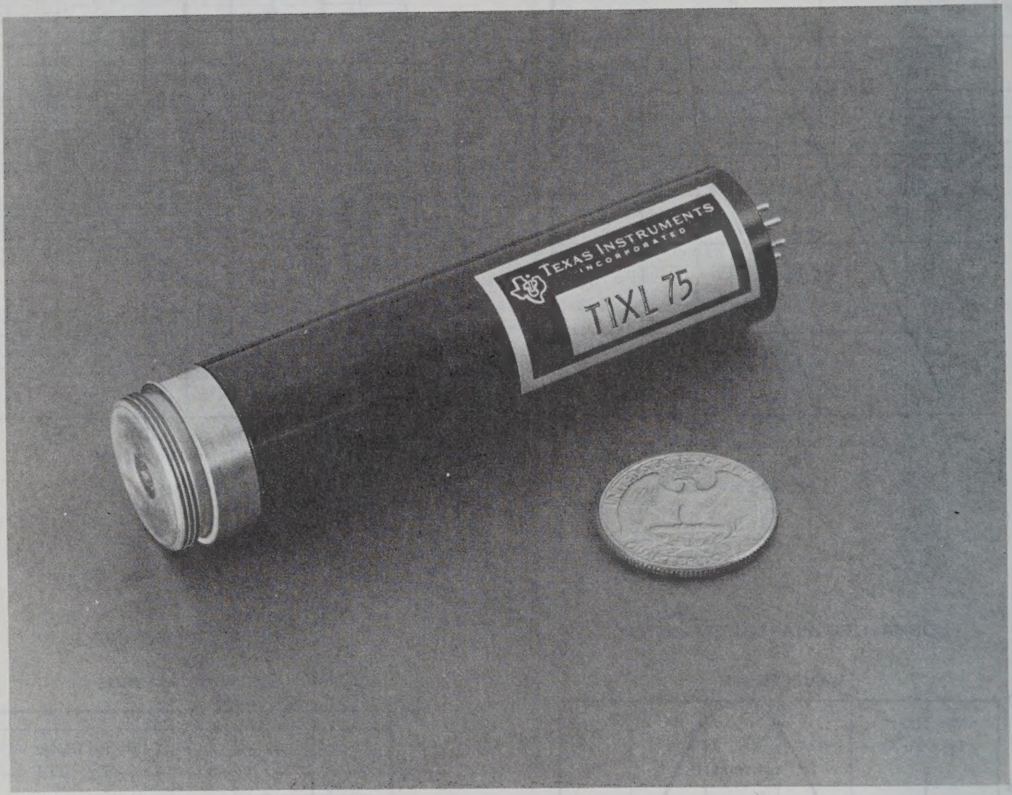
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INCORPORATED
TIXL 75

TYPE TIXL70
SILICON AVALANCHE PHOTODETECTOR HEAD

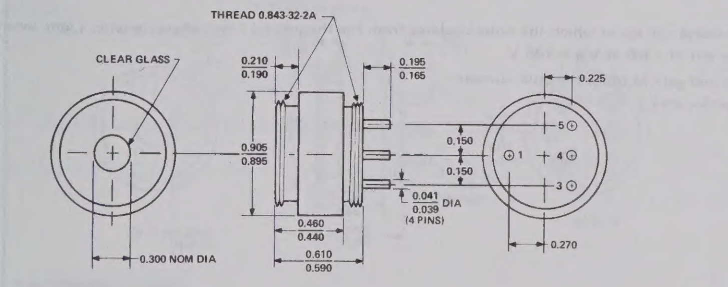
- Sensitive Silicon Avalanche Photodiode
- High-Frequency Photocurrent Gain
- Temperature-Tracking Voltage Reference Diode
- Designed for 0.9 μm Wavelength
- Mates with TIXL73 Amplifier and Bias Module

description

The TIXL70 is a silicon photodetector head designed for OEM applications such as laser range finders and optical communicators requiring high sensitivity. These devices contain a sensitive silicon avalanche photodiode (APD) for 0.9-μm wavelength and a temperature-sensing voltage reference diode (REF) mounted in a case which mates with the TIXL73 electronics section to form a complete photo-receiver module.

mechanical data

The device is in a hermetically sealed nickel-plated brass case. The pins, 0.040 inch in diameter, are in a configuration to mate with the TIXL73 electronics section. Threads on the front of the package are for mounting to the system. Threads on the back mate with the protective aluminum sleeve which covers the electronics section. A flat window of borosilicate glass, 0.060 inch thick and 0.305 inch in diameter, is on the front center of the package. The 0.030-inch-diameter APD is mounted in the center of the package, 0.075 inch behind the front surface. Weight of the detector head is approximately 20 grams.



1. REF Anode
2. Omitted
3. APD Anode
4. APD Cathode
5. Case, REF Cathode
6. Omitted

PLUG DIMENSIONS ARE NOMINAL
ALL DIMENSIONS ARE IN INCHES

TENTATIVE DATA SHEET
This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

TYPE TIXL70
SILICON AVALANCHE PHOTODETECTOR HEAD

absolute maximum ratings

Continuous Reverse Current at 25°C Case Temperature, APD and REF Diode	500 μA
Operating Case Temperature Range	−55°C to 100°C
Storage Temperature Range	−55°C to 100°C
Pin Soldering Temperature for 3 Minutes	160°C

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS‡		MIN	MAX	UNIT
APD Breakdown Voltage, $V_{(BR)}$		$I_R = 100\ \mu A$,	$H = 0$	140	200	V
Temperature Coefficient of Breakdown Voltage		$I_R = 100\ \mu A$, See Note 1	$H = 0$,	0.05	0.15	%/°C
Dark Current†	Bulk	$20 < M < M_T$,	$H = 0$		5	nA
	Surface	$20 < M < M_T$,	$H = 0$		50	nA
Photocurrent Gain at Sustained Avalanche Noise Threshold, M_T		$\lambda = 0.9\ \mu m$,	See Note 2	100		
Responsivity, $\overline{R}_0$		$\lambda = 0.9\ \mu m$, $V_R = 60$ V,	$f = 3$ kHz, $R_L \leqslant 1\ k\Omega$	0.2		A/W
APD Total Capacitance, C_T		$V_R = 100$ V,	$f = 1$ MHz		12	pF
APD Series Resistance, R_S		$f = 900$ MHz			10	Ω
Reference Voltage, V_Z		$I_Z = 100\ \mu A$		140	200	V
Temperature Coefficient of Reference Voltage		$I_Z = 100\ \mu A$, See Note 1	$H = 0$,	0.05	0.15	%/°C

NOTES: 1. Temperature coefficient $= \left[\dfrac{V_{(BR)}\ @\ 60^\circ C - V_{(BR)}\ @\ -40^\circ C}{V_{(BR)}\ @\ 25^\circ C}\right] \dfrac{100\%}{100^\circ C}$ or $\left[\dfrac{V_Z\ @\ 60^\circ C - V_Z\ @\ -40^\circ C}{V_Z\ @\ 25^\circ C}\right] \dfrac{100\%}{100^\circ C}$.

2. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. Light intensity is as required to give a photocurrent of 1 nA at $V_R = 100$ V.

†Dark current is the sum of surface current and gain M times the bulk current.

‡H is the incident radiant power per unit active area.

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TYPES TIXL71, TIXL72
GERMANIUM AVALANCHE PHOTODETECTOR HEADS

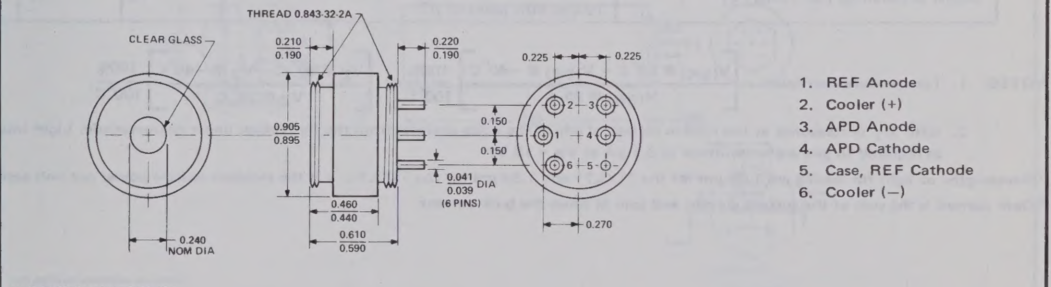
- Sensitive Germanium Avalanche Photodiode
- High-Frequency Photocurrent Gain
- Internal Thermoelectric Cooler
- Temperature-Tracking Voltage Reference Diode
- Designed for 1.06 and 1.54 μm Wavelengths
- Mates with TIXL73 Amplifier and Bias Module

description

The TIXL71 and TIXL72 are germanium photodetector heads designed for OEM applications requiring high sensitivity such as laser range finders and optical communicators. These devices contain a sensitive germanium avalanche photodiode (APD) for wavelengths of either 1.06 μm or 1.54 μm, a temperature-sensing voltage reference diode (REF), and an internal thermoelectric cooler mounted in a case which mates with the TIXL73 electronics section to form a complete photo-receiver module.

mechanical data

The devices are in hermetically sealed gold-plated brass cases. The 0.040-inch pins are in a configuration to mate with the TIXL73 electronics section. Threads on the front of the package are for mounting to the system and provide a heat sink for the thermoelectric-cooler power dissipation. Threads on the back mate with the protective aluminum sleeve which covers the electronics section. A flat window of borosilicate glass, 0.005 to 0.025 inch thick and 0.240 inch in diameter, is on the front center of the package. The 0.010-inch-diameter APD is mounted in the center of the package, 0.150 inch behind the front surface. Weight of the detector head is approximately 32 grams.



PLUG DIMENSIONS ARE NOMINAL
ALL DIMENSIONS ARE IN INCHES

TENTATIVE DATA SHEET
This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

TYPES TIXL71, TIXL72
GERMANIUM AVALANCHE PHOTODETECTOR HEADS

absolute maximum ratings

Continuous Reverse Current at (or below) 25°C Case Temperature, APD and REF Diode	500 µA
Thermoelectric Cooler Current, I_{CC}, at (or below) 25°C Case Temperature	2 A
Operating Case Temperature Range	−40°C to 60°C
Storage Temperature Range	−55°C to 100°C
Pin Soldering Temperature for 3 Minutes	140°C

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TIXL71		TIXL72		UNIT
					MIN	MAX	MIN	MAX	
APD Breakdown Voltage, $V_{(BR)}$		I_R = 100 µA,	H = 0		30	50	85	150	V
Temperature Coefficient of Breakdown Voltage		I_R = 100 µA,	H = 0,	See Note 1	0.1	0.2	0.1	0.2	%/°C
Dark Current‡	Bulk	10 < M < M_T,	I_{CC} = 0,	H = 0		0.4		0.6	µA
		10 < M < M_T,	I_{CC} = 1.8 A,	H = 0		30		50	nA
	Surface	10 < M < M_T,	I_{CC} = 0,	H = 0		15		20	µA
		10 < M < M_T,	I_{CC} = 1.8 A,	H = 0		2		3	µA
Photocurrent Gain at Sustained Avalanche Noise Threshold, M_T		See Note 2			30		20		
Responsivity, $\overline{R}_0$		f = 3 kHz, $R_L \leq 1$ kΩ	I_{CC} = 0,	V_R = 15 V,	0.45		0.4		A/W
APD Total Capacitance, C_T		V_R = 15 V,	f = 1 MHz			10		5	pF
APD Series Resistance, R_S		f = 900 MHz				30		60	Ω
REF Breakdown Voltage, V_Z		I_Z = 100 µA			30	50	85	125	V
Temperature Coefficient of Reference Voltage		I_Z = 100 µA,	H = 0,	See Note 1	0.1	0.2	0.1	0.2	%/°C
Thermoelectric Cooler Voltage, V_{CC}		I_{CC} = 1.8 A				0.85		0.85	V
Cooler Differential Temperature, ΔT		I_{CC} = 1.8 A			40		40		°C
Cooler Differential Fall-Time, $t_{\Delta T}$		I_{CC} = 1.8 A, 10% to 90% point of ΔT				15		15	s

NOTES: 1. Temperature coefficient = $\left[\frac{V_{(BR)} @ 60°C - V_{(BR)} @ -40°C}{V_{(BR)} @ 25°C}\right] \frac{100\%}{100°C}$ or $\left[\frac{V_Z @ 60°C - V_Z @ -40°C}{V_Z @ 25°C}\right] \frac{100\%}{100°C}$.

2. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. Light intensity is as required to give a photocurrent of 0.1 µA at V_R = 15 V.

†Wavelengths of light for testing are 1.06 µm for the TIXL71 and 1.54 µm for the TIXL72. H is the incident radiant power per unit active area.

‡Dark current is the sum of the surface current and gain M times the bulk current.

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TYPE TIXL73
DETECTOR MODULE ELECTRONICS SECTION

- Amplifier and Bias Circuits for Avalanche Photodiodes
- Epoxy Encapsulated
- Mates with Silicon and Germanium Detector Heads, TIXL70, TIXL71, TIXL72
- Amplifier Bandwidth of 50 MHz Typ
- Externally Controllable, Precision Gain-Regulation Circuit

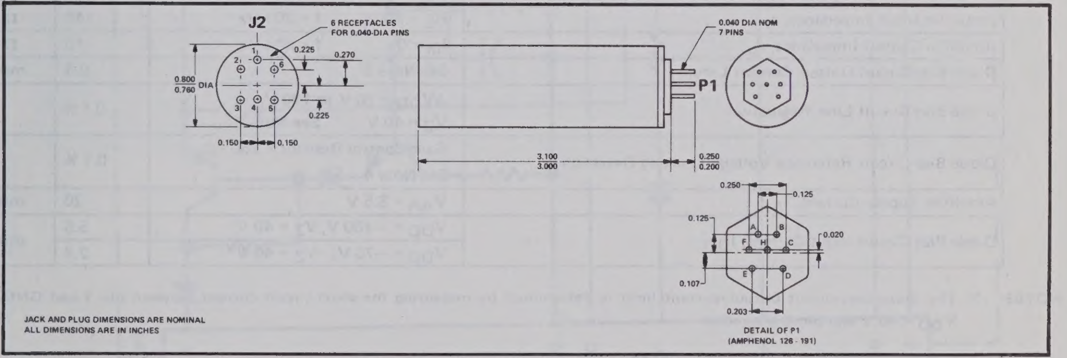
description

The TIXL73 is an electronics section designed for use with the silicon and germanium avalanche photodetector (APD) heads such as the TIXL70, TIXL71, or TIXL72. When mated with the detector head and a mounting sleeve, the assembly is a complete photodetector module.

The TIXL73 contains a low-noise, 50-MHz-bandwidth, transimpedance amplifier, the TIXL151. Also contained is a regulated avalanche gain bias circuit. This circuit is basically a series regulator circuit with the output voltage controlled by the breakdown voltage of the reference diode in the detector head. As temperature changes, the reference voltage correspondently changes and the APD bias voltage is automatically adjusted to maintain constant avalanche gain. The bias circuit includes a constant 300-μA current source for the reference diode and a 500-μA-output-current limiter for diode protection. The APD gain is externally set by a resistor or transistor for active gain control.

mechanical data

The device is an epoxy encapsulated unit, cylindrical in shape. A jack on the front mates with the detector head, TIXL70, TIXL71, or TIXL72. A seven-pin plug on the rear provides for the electrical connections to the complete module. Total weight of the electronics section is approximately 45 grams.



JACK AND PLUG DIMENSIONS ARE NOMINAL
ALL DIMENSIONS ARE IN INCHES

TENTATIVE DATA SHEET
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TYPE TIXL73
DETECTOR MODULE ELECTRONICS SECTION

absolute maximum ratings over operating case temperature range (unless otherwise specified)

Amplifier Supply Voltage, V_{AA} (See Note 1)	9.5 V
Diode-Bias-Circuit Supply Voltage, V_{DD} (See Note 1)	−200 V
Diode-Bias-Circuit Supply Voltage with Respect to Pin 1, $V_{DD} - V_{①}$	−60 V
Diode-Bias-Circuit Supply Voltage with Respect to Pin 3, $V_{DD} - V_{③}$	−60 V
Current through Cooler Supply Terminals, I_{CC}	5 A
Operating Case Temperature Range	−40°C to 60°C
Storage Temperature Range	−55°C to 125°C

NOTE 1: All voltage values are with respect to pin D (GND) unless otherwise noted.

electrical connections to output plug, P1 (see schematic)

PIN	DESCRIPTION	POWER REQUIRED
A	Cooler Supply Input (+)	As required by Cooler, 5 A max.
B	Cooler Supply Input (−)	
C	Gain-Control Resistor†	
D	GND (Common for Pins C, E, F, and H)	
E	Diode-Bias-Circuit Supply	20 V to 60 V above V_Z, 5.3 mA max.
F	Amplifier Supply	8.5 ± 0.5 V, 20 mA max.
H	Signal Output	

† For constant-avalanche-gain operation, a low-temperature-coefficient resistor should be connected between pins C and D. The nominal value is 240 kΩ.

electrical characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Equivalent Input Noise Current, i_n	$R_L = 50\ \Omega$, f = 10 kHz to 150 MHz		7	$pA/\sqrt{H_z}$
Amplifier Bandwidth (3-dB), BW‡	$R_L = 50\ \Omega$	40		MHz
Forward Transfer Impedance, z_f	$R_L = 50\ \Omega$	2.8		kΩ
Amplifier Input Impedance, z_i	$R_L = 50\ \Omega$, f = 20 kHz		140	Ω
Amplifier Output Impedance, z_o	$I_{in} = 0$, f = 20 kHz		10	Ω
Diode-Bias-Circuit Output Current Limit	See Note 2		0.5	mA
Diode-Bias-Circuit Line Regulation	ΔV_{DD} = 70 V to 100 V, V_Z = 40 V, See Note 3		0.1 %	
Diode-Bias-Circuit Reference Voltage Tracking Deviation	Gain-Control Resistor = 250 kΩ, See Note 4		0.1 %	
Amplifier Supply Current, I_{AA}	V_{AA} = 8.5 V		20	mA
Diode-Bias-Circuit Input Current, I_{DD}	V_{DD} = −100 V, V_Z = 40 V		5.5	mA
	V_{DD} = −70 V, V_Z = 40 V		2.4	

NOTES: 2. The diode-bias-circuit output-current limit is determined by measuring the short-circuit current between pin 3 and GND with V_{DD} = 40 V and pin C grounded.

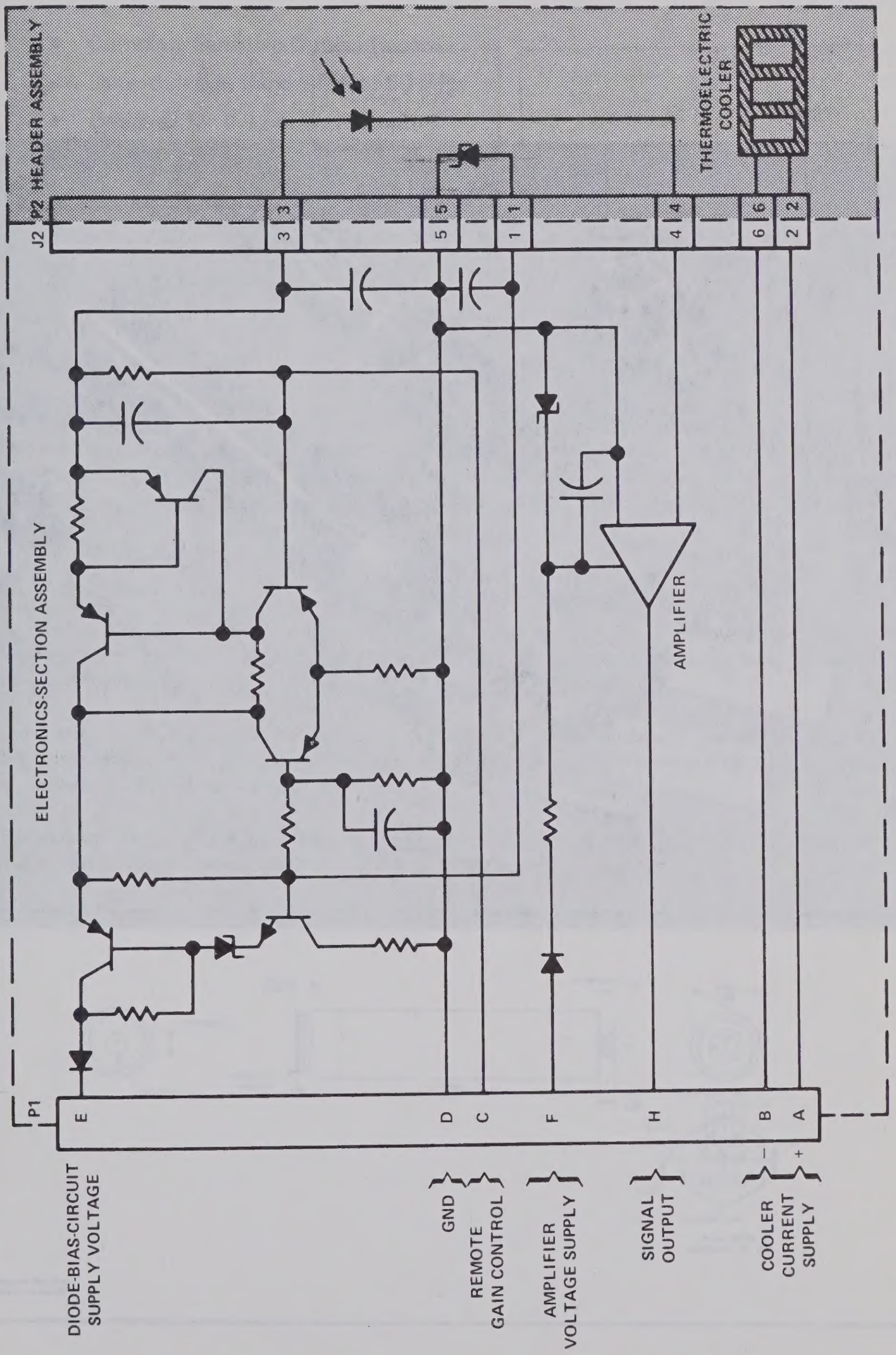
3. Diode-bias-circuit line regulation = $\frac{\Delta V_{③}}{\Delta V_{DD}} \times 100\%$ where $V_{③}$ is the voltage at pin 3.

The test is made with a 40-volt reference diode connected between pins 1 and 5.

4. Diode-bias-circuit reference voltage tracking deviation = $\frac{\Delta(V_{③} - V_Z)}{\Delta V_Z} \times 100\%$ where $V_{③}$ is the voltage at pin 3.

‡For this amplifier, the bandwidth extends from dc to the upper cutoff frequency.

schematic


P2 HEADER ASSEMBLY
THERMOELECTRIC COOLER
J2
3
5
1
4
6
2
ELECTRONICS-SECTION ASSEMBLY
AMPLIFIER
P1
E
D
C
F
H
B
A
−
+
DIODE-BIAS-CIRCUIT SUPPLY VOLTAGE
GND
REMOTE GAIN CONTROL
AMPLIFIER VOLTAGE SUPPLY
SIGNAL OUTPUT
COOLER CURRENT SUPPLY

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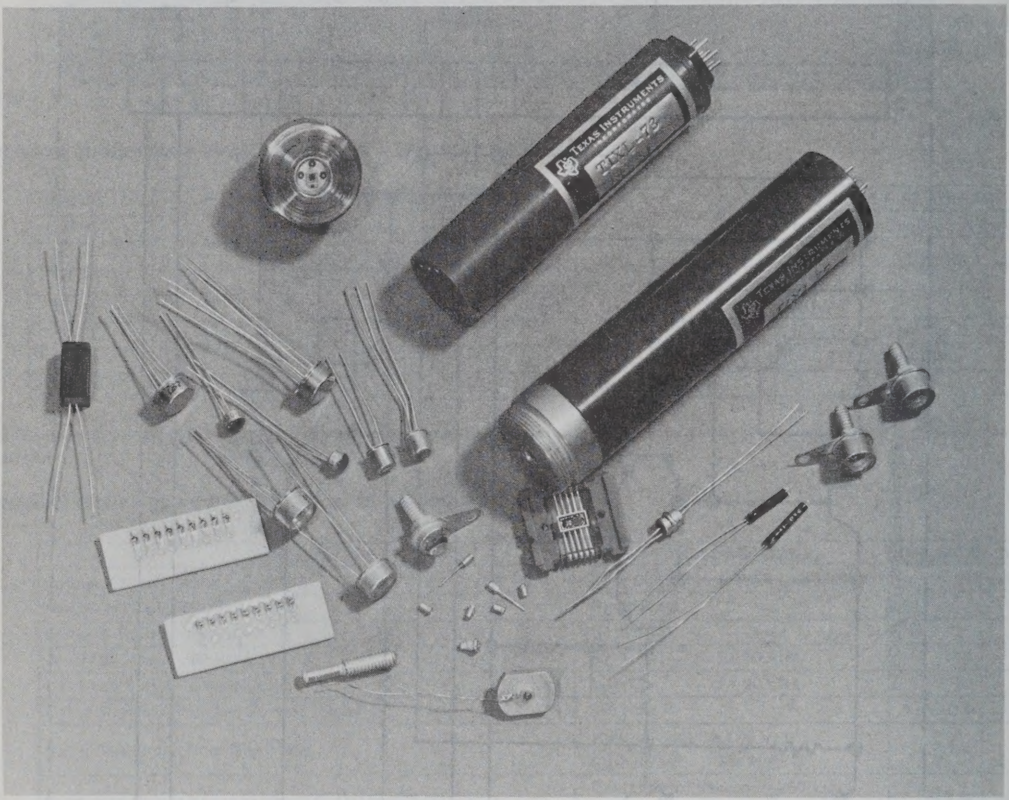
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TYPE TIXL74
SILICON AVALANCHE PHOTODETECTOR MODULE

- Complete Sensitive Optical Receiver
- Demodulation Bandwidth of 50 MHz
- Designed for 0.9 μm Wavelength
- Typical Responsivity of 2×10^5 V/W
- Typical System Noise Equivalent Power of 2×10^{-13} W/$\sqrt{\text{Hz}}$
- Small Cylindrical Shape, 0.9-Inch Diameter by 4-Inch Length
- Automatic Regulated Avalanche-Gain Bias Circuit
- Low Power Consumption

description

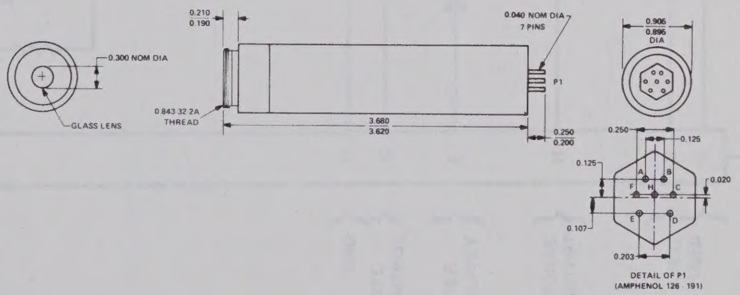
The TIXL74 is a complete avalanche photodetector module designed for OEM applications at 0.9 μm. The unit contains a silicon avalanche photodiode (APD), a temperature-sensing voltage reference diode, a low-noise high-frequency thin-film amplifier, and a regulated avalanche-gain bias circuit. The avalanche gain is externally programmable. The high sensitivity of these devices makes them ideally suited for laser range finders and optical communicators.

mechanical data

The TIXL74 consists of a photodetector head (TIXL70) mated to an electronics section (TIXL73). A black, anodized aluminum sleeve protects the encapsulated electronics and attaches to the nickel-plated brass detector head, forming a single assembly 0.19 inch in diameter and 4 inches in length.

Threads on the front of the package are for mounting to the system. A flat window of borosilicate glass, 0.060 inch thick and 0.030 inch in diameter, is on the front center of the package. The 0.030-inch-diameter APD is mounted in the center of the package, 0.075 inch behind the front surface.

The seven-pin plug on the rear of the module provides for the electrical connections. A mating jack is supplied with the module. Total weight of the complete module is approximately 100 grams.



DETAIL OF P1
(AMPHENOL 126 - 191)

PLUG DIMENSIONS ARE NOMINAL
ALL DIMENSIONS ARE IN INCHES

TENTATIVE DATA SHEET

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TYPE TIXL74
SILICON AVALANCHE PHOTODETECTOR MODULE

absolute maximum ratings over operating case temperature range (unless otherwise noted)

Amplifier Supply Voltage, V_{AA} (See Note 1)	9.5 V
Diode-Bias-Circuit Supply Voltage, V_{DD} (see Note 1)	−200 V
Operating Case Temperature Range	−40°C to 60°C
Storage Temperature Range	−55°C to 125°C

NOTE 1: All voltage values are with respect to pin D (GND) unless otherwise noted.

electrical connections to plug, P1 (see schematic)

PIN	DESCRIPTION	POWER REQUIRED
A	No Connection	
B	No Connection	
C	Gain Control Resistor[†]	
D	GND (Common for Pins C, E, F, and H)	
E	Diode-Bias-Circuit Supply	190 V to 200 V, 5 mA max.
F	Amplifier Supply	8.5 ± 0.5 V, 20 mA max.
H	Signal Output	

[†] For constant-avalanche-gain operation, a low-temperature-coefficient resistor should be connected between pins C and D. The resistance value for M = 125 is supplied with individual module data. The nominal value is 240 kΩ.

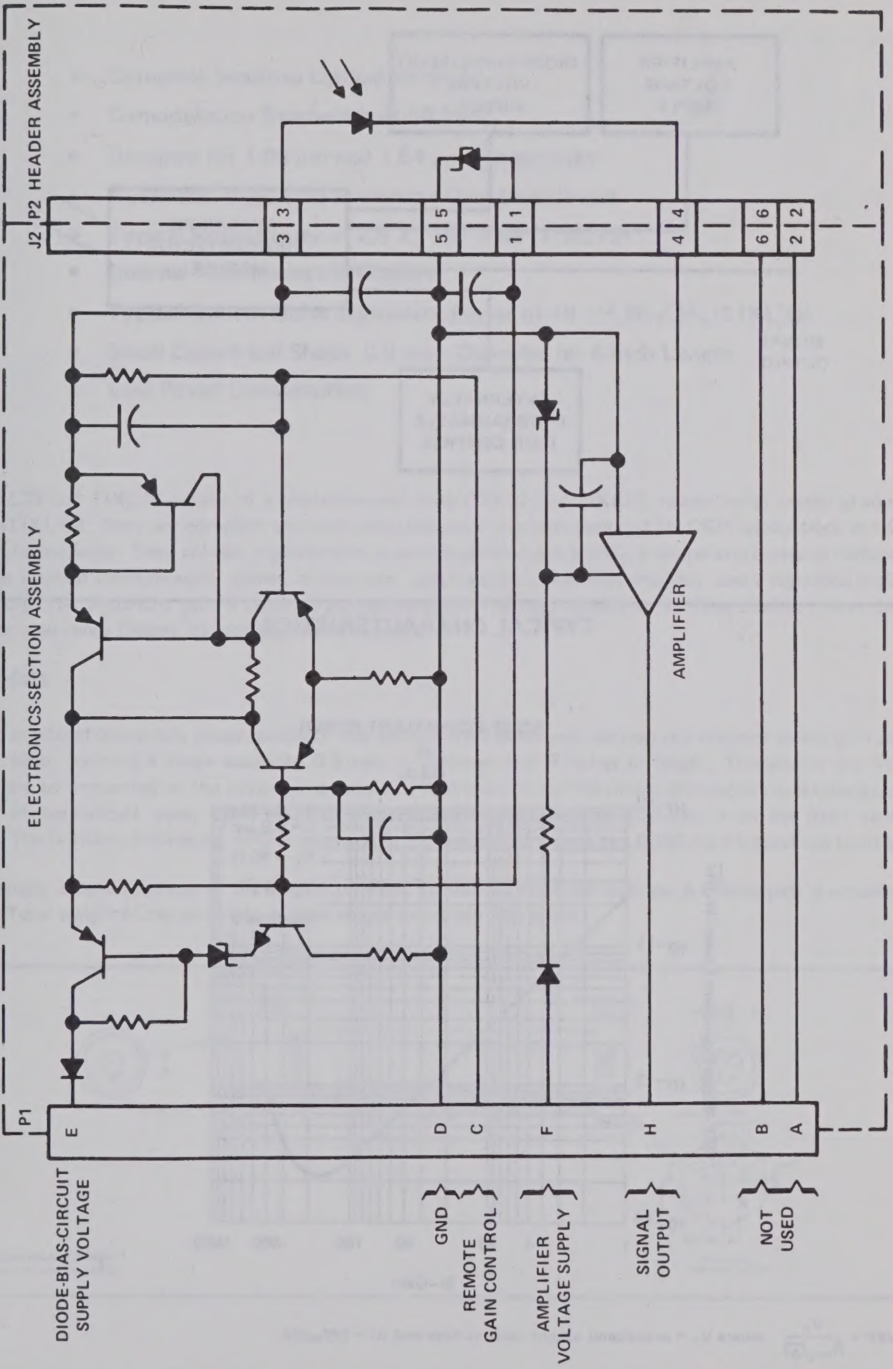
electrical characteristics at 25°C case temperature, $R_L = 50\ \Omega$, M = 125

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Module Responsivity, $\bar{R}_m$	f = 3 kHz	75	150	V/mW
Noise Equivalent Power, NEP, (See Note 2)	$\lambda = 0.9\ \mu m$		0.5	$pW/\sqrt{Hz}$
APD Gain Variation over Operating Temperature Range, ΔM/M	$T_C = -40°C$ to 60°C	±10%		
Module Bandwidth (3-dB), B_m[‡]		40		MHz
Amplifier Output Impedance, z_o	f = 20 kHz		10	Ω

NOTE 2: $NEP = \frac{V_n}{\bar{R}_m \sqrt{\Delta f}}$,where V_n = broadband output noise voltage and $\Delta f = B_m \pi/2$.

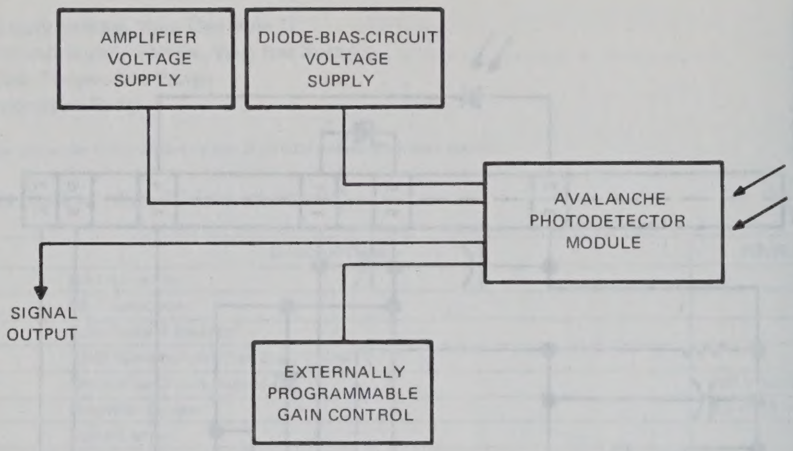
[‡] For this module, the bandwidth extends from dc to the upper cutoff frequency.

schematic


J2 P2 HEADER ASSEMBLY
3 3
5 5
1 1
4 4
6 6
2 2
ELECTRONICS-SECTION ASSEMBLY
AMPLIFIER
P1
E
D
C
F
H
B
A
DIODE-BIAS-CIRCUIT SUPPLY VOLTAGE
GND
REMOTE GAIN CONTROL
AMPLIFIER VOLTAGE SUPPLY
SIGNAL OUTPUT
NOT USED

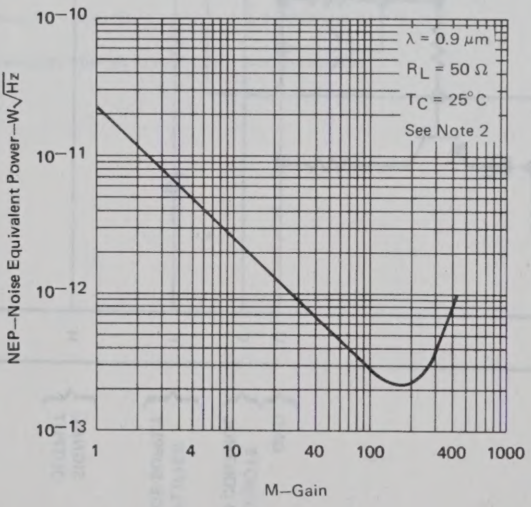
TYPE TIXL74
SILICON AVALANCHE PHOTODETECTOR MODULE

operational block diagram


AMPLIFIER VOLTAGE SUPPLY
DIODE-BIAS-CIRCUIT VOLTAGE SUPPLY
AVALANCHE PHOTODETECTOR MODULE
SIGNAL OUTPUT
EXTERNALLY PROGRAMMABLE GAIN CONTROL

TYPICAL CHARACTERISTICS

NOISE EQUIVALENT POWER
vs
GAIN



NOTE 2: NEP = $\frac{V_n}{R_m\sqrt{\Delta f}}$, where V_n = broadband output noise voltage and $\Delta f = BW_m\pi/2$.

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TYPES TIXL75, TIXL76
GERMANIUM AVALANCHE PHOTODETECTOR MODULES

- Complete Sensitive Optical Receiver
- Demodulation Bandwidth of 50 MHz
- Designed for 1.06 μm and 1.54 μm Wavelengths
- Automatic Regulated Avalanche-Gain Bias Circuit
- Typical Responsivity of 2.8 X 10^4 V/W (TIXL75)
- Internal Thermoelectric Coolers
- Typical System Noise Equivalent Power of 10^{-12} W/$\sqrt{\text{Hz}}$ (TIXL75)
- Small Cylindrical Shape, 0.9-Inch Diameter by 4-Inch Length
- Low Power Consumption

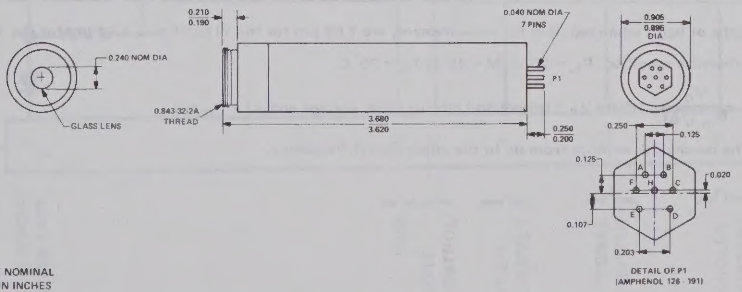
description

The TIXL75 and TIXL76 consist of a photodetector head (TIXL71 or TIXL72, respectively) mated to an electronics section (TIXL73). They are complete avalanche photodetector modules designed for OEM applications at 1.06 μm and 1.54 μm, respectively. They contain a germanium avalanche photodiode (APD), a temperature-sensing voltage reference diode, an internal thermoelectric cooler, a low-noise high-frequency thin-film amplifier, and a regulated avalanche-gain bias circuit. The avalanche gain is externally programmable. The high sensitivity of these devices makes them ideally suited for laser range finders and optical communicators.

mechanical data

A black, anodized aluminum sleeve protects the encapsulated electronics section and attaches to the gold-plated brass detector head, forming a single assembly 0.9 inch in diameter and 4 inches in length. Threads on the front of the package are for mounting to the system and provide a heat sink for the thermoelectric-cooler power dissipation. A flat window of borosilicate glass, 0.005 to 0.025 inch thick and 0.240 inch in diameter, is on the front center of the package. The 0.010-inch-diameter APD is mounted in the center of the package, 0.150 inch behind the front surface.

The seven-pin plug on the rear of the module provides for the electrical connections. A mating jack is supplied with the module. Total weight of the complete module is approximately 100 grams.



PLUG DIMENSIONS ARE NOMINAL
ALL DIMENSIONS ARE IN INCHES

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absolute maximum ratings over operating case temperature range (unless otherwise specified)

Amplifier Supply Voltage, V_{AA} (See Note 1)		9.5 V
Diode-Bias-Circuit Supply Voltage, V_{DD} (See Note 1):	TIXL75	−100 V
	TIXL76	−160 V
Cooler Supply Current, I_{CC}, at 25°C Case Temperature		2 A
Operating Case Temperature Range		−40°C to 60°C
Storage Temperature Range		−55°C to 100°C

NOTE 1: All voltage values are with respect to pin D (GND) unless otherwise noted.

electrical connections to output plug, P1 (see schematic)

PIN	DESCRIPTION	POWER REQUIRED
A	Cooler Supply Input (+)	0 to 1.8 A at 0 to 0.7 V
B	Cooler Supply Input (−)	
C	Gain Control Resistor†	
D	GND (Common for Pins C, E, F, and H)	
E	Diode-Bias-Circuit Supply, TIXL75	−70 to −100 V, 5.3 mA max.
	TIXL76	−125 to −160 V, 5.3 mA max.
F	Amplifier Supply	8.5 ± 0.5 V, 20 mA max.
H	Signal Output	

†For constant-avalanche-gain operation, a low-temperature-coefficient resistor should be connected between pins C and D. The resistance value for M = 15 is supplied with individual module data. The nominal value is 240 kΩ.

electrical characteristics at 25°C case temperature (unless otherwise specified)

PARAMETER	TEST CONDITIONS (SEE NOTES 2 AND 3)	TIXL75		TIXL76		UNIT
		MIN	MAX	MIN	MAX	
Module Responsivity, $\overline{R}_m$	I_{CC} = 1.8 A, f = 3 kHz	20		6		V/mW
Noise Equivalent Power, NEP (See Note 4)	I_{CC} = 0		3		6	pW/$\sqrt{\text{Hz}}$
	I_{CC} = 1.8 A		1.5		6	
	I_{CC} = 1.8 A, T_C = 60°C		2		6	
APD Gain Variation over Operating Temperature Range, ΔM/M	T_C = −40°C to 60°C		±10%		±10%	
Module Bandwidth (3-dB), B_m‡		40		40		MHz
Amplifier Output Impedance, z_o	f = 20 kHz		10		10	Ω

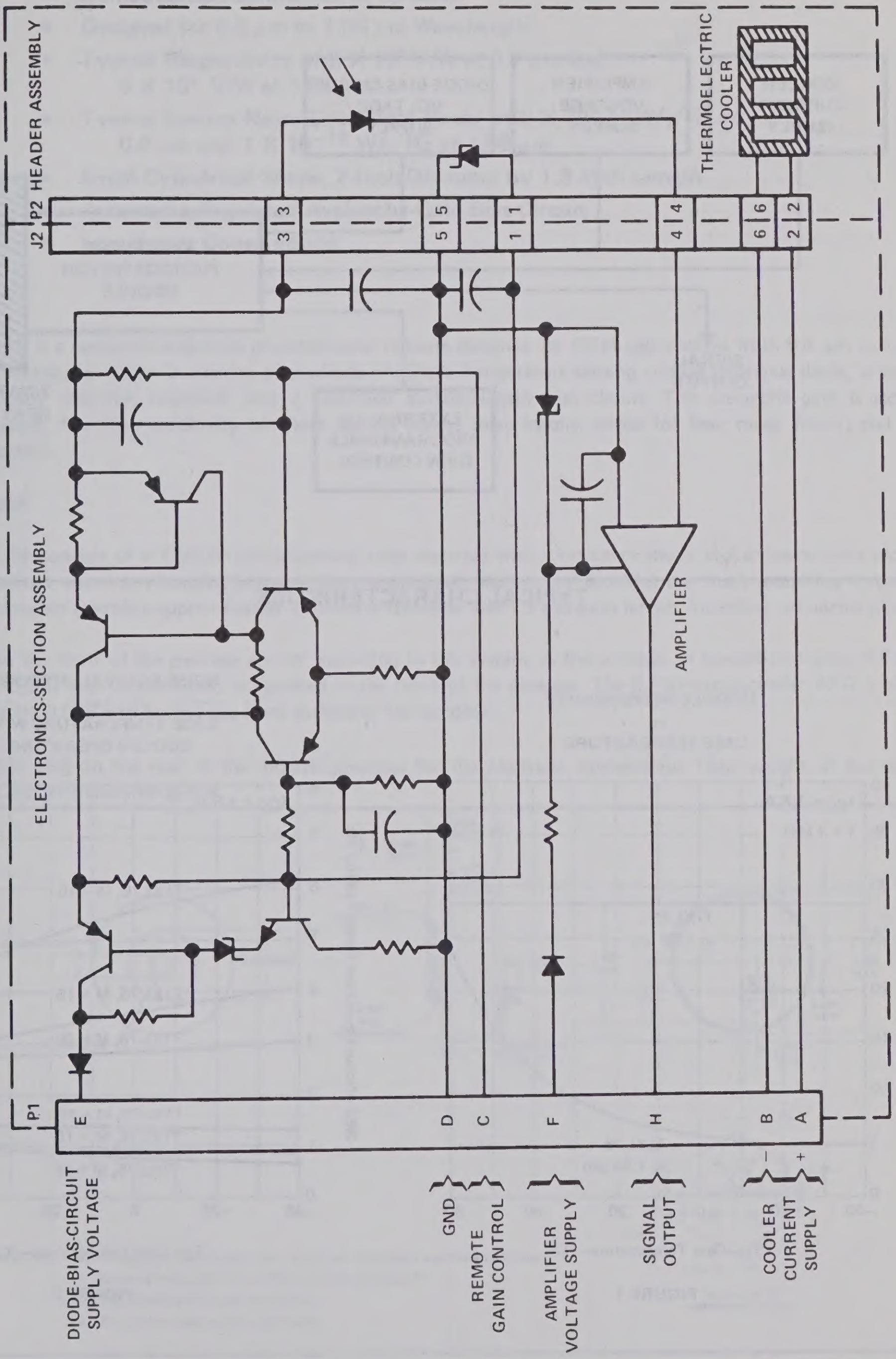
NOTES: 2. Wavelengths of light, when required for measurement, are 1.06 μm for the TIXL75 and 1.54 μm for the TIXL76.

3. Unless otherwise specified, R_L = 50 Ω, M = 15 at T_C = 25°C.

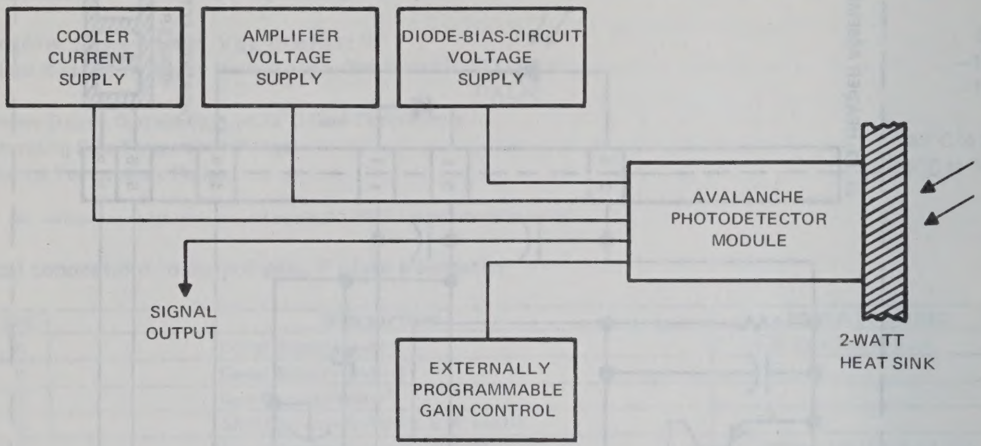
4. $\text{NEP} = \frac{V_n}{\overline{R}_m \sqrt{\Delta f}}$, where V_n = broadband output noise voltage and $\Delta f = B_m \pi/2$.

‡For these modules, the bandwidth extends from dc to the upper cutoff frequency.

schematic


J2 P2 HEADER ASSEMBLY
THERMOELECTRIC COOLER
3 3
5 5
1 1
4 4
6 6
2 2
ELECTRONICS-SECTION ASSEMBLY
AMPLIFIER
P1
E
D
C
F
H
B
A
−
+
DIODE-BIAS-CIRCUIT SUPPLY VOLTAGE
GND
REMOTE GAIN CONTROL
AMPLIFIER VOLTAGE SUPPLY
SIGNAL OUTPUT
COOLER CURRENT SUPPLY

operational block diagram


COOLER CURRENT SUPPLY
AMPLIFIER VOLTAGE SUPPLY
DIODE-BIAS-CIRCUIT VOLTAGE SUPPLY
AVALANCHE PHOTODETECTOR MODULE
SIGNAL OUTPUT
EXTERNALLY PROGRAMMABLE GAIN CONTROL
2-WATT HEAT SINK

TYPICAL CHARACTERISTICS

MODULE RESPONSIVITY
vs
CASE TEMPERATURE

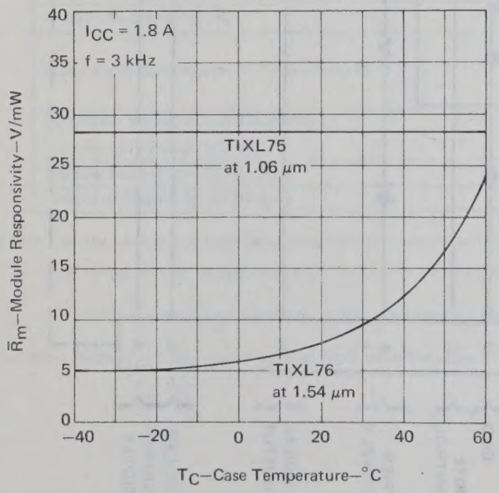


FIGURE 1

NOISE EQUIVALENT POWER
vs
CASE TEMPERATURE WITH
COOLER OPERATING

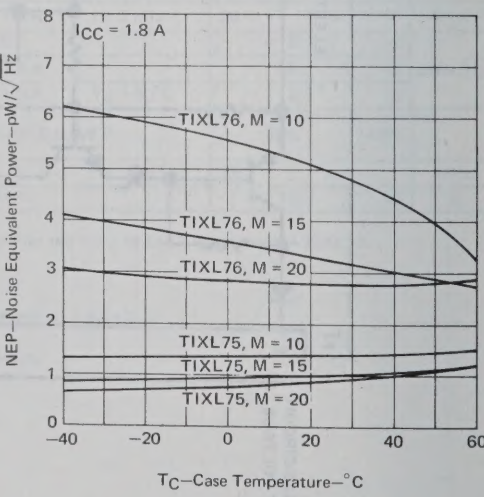


FIGURE 2

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TYPE TIXL79
LOW-PROFILE SILICON AVALANCHE PHOTODETECTOR MODULE

TYPE TIXL79
BULLETIN NO. DL-S 7111556, NOVEMBER 1971

- **Complete Sensitive Optical Receiver**
- **Demodulation Bandwidth of 50 MHz**
- **Designed for 0.9 μm to 1.06 μm Wavelength**
- **Typical Responsivity of 2×10^5 V/W at 0.9 μm and 5×10^4 V/W at 1.06 μm**
- **Typical System Noise Equivalent Power of 2×10^{-13} W/$\sqrt{\text{Hz}}$ at 0.9 μm and 1×10^{-12} W/$\sqrt{\text{Hz}}$ at 1.06 μm**
- **Small Cylindrical Shape, 2-Inch Diameter by 1.3-Inch Length**
- **Automatic Regulated Avalanche-Gain Bias Circuit**
- **Low Power Consumption**

description

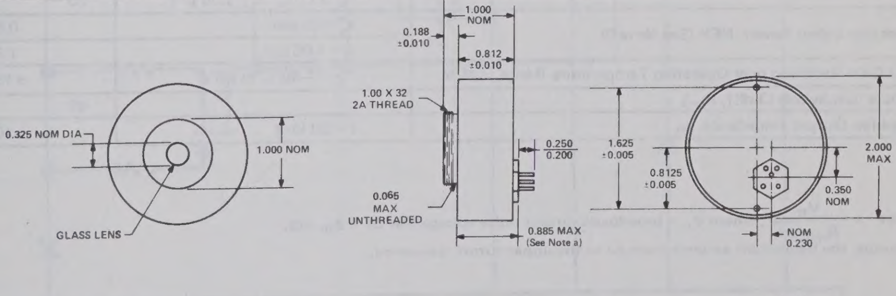
The TIXL79 is a complete avalanche photodetector module designed for OEM applications from 0.9 μm to 1.06 μm. The unit contains a silicon avalanche photodiode (APD), a temperature-sensing voltage reference diode, a low-noise high-frequency thin-film amplifier, and a regulated avalanche-gain bias circuit. The avalanche gain is externally programmable. The high sensitivity of these devices makes them ideally suited for laser range finders and optical communicators.

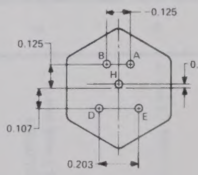
mechanical data

The TIXL79 consists of a TIXL59 photodetector chip matched with a reference diode and an electronics section. A black anodized aluminum housing protects the encapsulated electronics, provides the front mounting threads, and forms a complete assembly approximately 2 inches in diameter and 1.3 inches in length, including connector pins.

Threads on the front of the package are for mounting to the system. A flat window of borosilicate glass, 0.060 inch thick and 0.300 inch in diameter, is centered in the front of the package. The 0.030-inch-diameter APD is centered approximately 0.075 inch behind the front surface of the window.

The five-pin plug on the rear of the module provides for the electrical connections. Total weight of the complete module is approximately 80 grams.





DETAIL OF P1
(AMPHENOL 126-216)

NOTES:
- a. Irregularities which may exist on the back surface will not extend beyond the seating plane of plug P1.
- b. All dimensions are in inches.
- c. Plug dimensions are nominal.

TENTATIVE DATA SHEET
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TYPE TIXL79
LOW-PROFILE SILICON AVALANCHE PHOTODETECTOR MODULE

absolute maximum ratings over operating case temperature range (unless otherwise noted)

Amplifier Supply Voltage, V_{AA} (See Note 1)	9.5 V
Diode-Bias-Circuit Supply Voltage, V_{DD} (See Note 1)	−230 V
Operating Case Temperature Range	−40°C to 60°C
Storage Temperature Range	−55°C to 125°C

NOTE 1: All voltage values are with respect to pin E (GND).

electrical connections to plug P1 (see schematic)

PIN	DESCRIPTION	POWER REQUIRED
A	Signal Output	
B	Amplifier Supply	8.5 ± 0.5 V, 20 mA max
D	Diode-Bias-Circuit Supply	MIN† to 230 V, 2 mA max
E	Ground	
H	Gain Control Resistor‡	

† The minimum required value of diode-bias-circuit supply voltage is supplied with other data for each individual module.

‡ For constant-avalanche-gain operation a low-temperature-coefficient resistor should be connected between pins E and H. The resistance value for M = 125 is supplied with other data for each individual module. The nominal value is 240 kΩ.

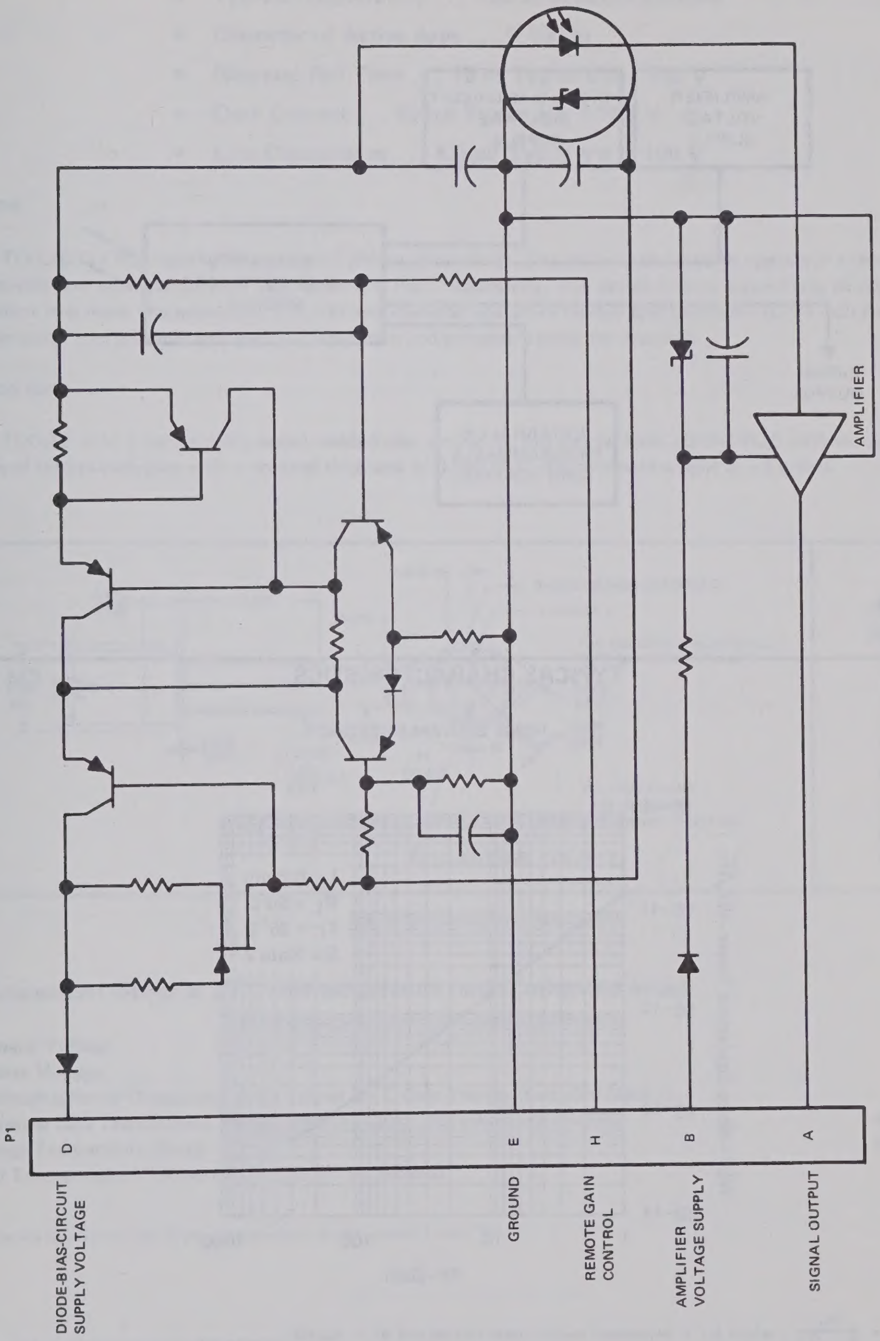
electrical characteristics at 25°C case temperature, $R_L = 50\ \Omega$, M = 125 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Module Responsivity, $\bar{R}_m$	f = 3 kHz, λ = 0.9 μm	75		V/mW
	f = 3 kHz, λ = 1.06 μm	20		
Noise Equivalent Power, NEP (See Note 2)	λ = 0.9 μm		0.5	pW/$\sqrt{\text{Hz}}$
	λ = 1.06 μm		1.5	
APD Gain Variation over Operating Temperature Range, ΔM/M	T_C = −40°C to 60°C		±15%	
Module Bandwidth (3-dB), B_m§		40		MHz
Amplifier Output Impedance, z_o	f = 20 kHz		10	Ω

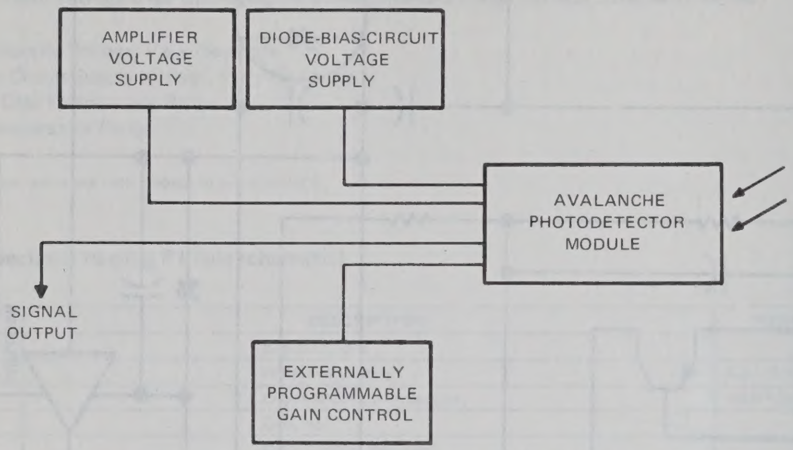
NOTE 2: NEP $= \dfrac{V_n}{\bar{R}_m\sqrt{\Delta f}}$, where V_n = broadband output noise voltage and $\Delta f = B_m\ \pi/2$.

§ For this module, the bandwidth extends from dc to the upper cutoff frequency.

module schematic

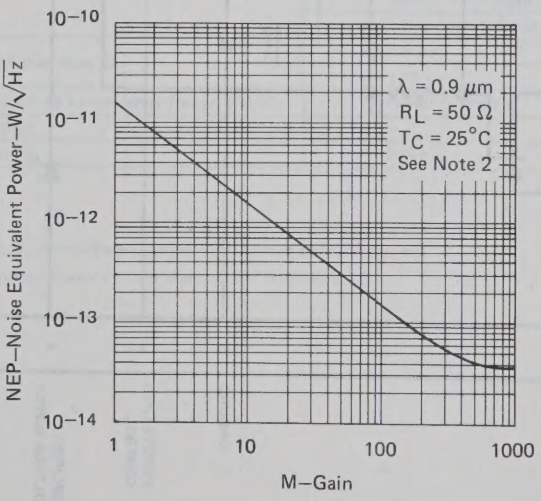

AMPLIFIER
P1
D
E
H
B
A
DIODE-BIAS-CIRCUIT SUPPLY VOLTAGE
GROUND
REMOTE GAIN CONTROL
AMPLIFIER VOLTAGE SUPPLY
SIGNAL OUTPUT

operational block diagram


AMPLIFIER VOLTAGE SUPPLY
DIODE-BIAS-CIRCUIT VOLTAGE SUPPLY
AVALANCHE PHOTODETECTOR MODULE
SIGNAL OUTPUT
EXTERNALLY PROGRAMMABLE GAIN CONTROL

TYPICAL CHARACTERISTICS

NOISE EQUIVALENT POWER
vs
GAIN



NOTE 2: NEP = $\frac{V_n}{R_m\sqrt{\Delta f}}$, where V_n = broadband output noise voltage and $\Delta f = B_m\pi/2$.

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

TYPE TIXL80
LARGE-AREA SILICON PHOTODIODE

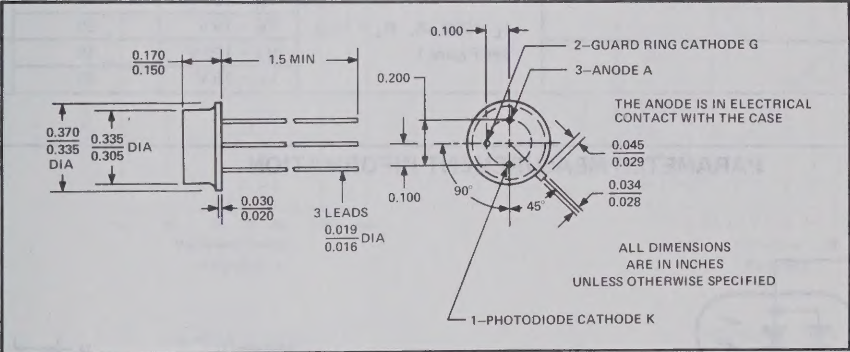
- Typical Responsivity . . . 0.55 A/W at 0.9 Microns
- Diameter of Active Area . . . 0.100 in
- Rise and Fall Time . . . 15 ns Typ at V_R = 100 V
- Dark Current . . . 15 nA Typ at V_R = 100 V
- Low Capacitance . . . 4.5 pF Typ at V_R = 100 V

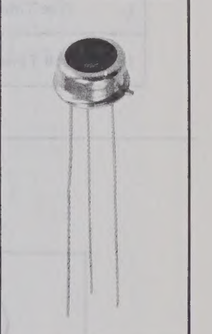
description

The TIXL80 is a high-speed *photoamperic*† silicon photodiode. The device is designed to operate in a reverse-bias mode to provide low capacitance with high speed and high responsivity. The device utilizes a guard-ring structure to provide excellent low noise characteristics. A 0.100-inch-diameter aperature located approximately 0.030 inch from the surface of the active area prevents extraneous illumination and provides a plane for focusing.

mechanical data

The TIXL80 is in a hermetically sealed welded case similar to, but shorter than, JEDEC TO-5 with window. The lens is made of borosilicate glass with a nominal thickness of 0.050 inch. Approximate weight is 1.2 grams.


0.170
0.150
1.5 MIN
0.370
0.335
DIA
0.335
0.305
DIA
0.030
0.020
3 LEADS
0.019
0.016
DIA
0.100
0.200
0.100
90°
45°
2–GUARD RING CATHODE G
3–ANODE A
THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE
0.045
0.029
0.034
0.028
ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
1–PHOTODIODE CATHODE K



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Forward Voltage	0.5 V
Reverse Voltage	200 V
Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

---

†Trademark of Texas Instruments Incorporated.

electrical characteristics at 25°C case temperature

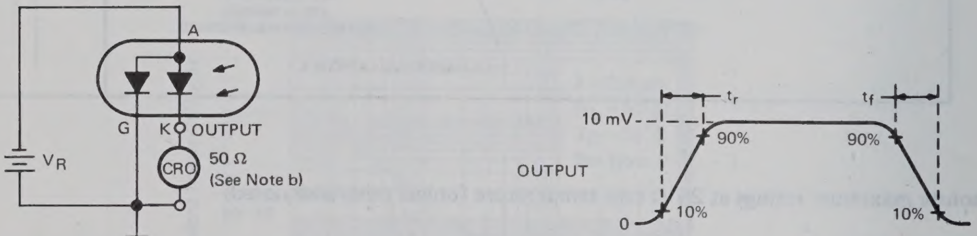
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)}$	Breakdown Voltage	I_R = 100 μA, H = 0,	See Note 2	200			V
I_D	Dark Current	V_R = 15 V, H = 0,	See Note 2		10		nA
		V_R = 100 V, H = 0,	See Note 2		15	500	
C_T	Total Capacitance	V_R = 15 V, f = 1 MHz			8.5		pF
		V_R = 100 V, f = 1 MHz			4.5	5.5	
$\bar{R}_O$	Responsivity	V_R = 15 V, λ = 0.9 μm			0.55		A/W
		V_R = 100 V, λ = 0.9 μm		0.4	0.55		
		V_R = 15 V, λ = 1.06 μm			0.20		
		V_R = 100 V, λ = 1.06 μm			0.20		

NOTE 2: Irradiance (H) is the radiant power per unit area upon a surface. Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TYPICAL	UNIT
t_r	Rise Time	I_L = 200 μA, R_L = 50 Ω, See Figure 1	V_R = 100 V	15	ns
			V_R = 15 V	50	
t_f	Fall Time		V_R = 100 V	15	ns
			V_R = 15 V	50	

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORM

NOTES: a. Input irradiance is supplied by a pulsed GaAs laser (λ = 0.9 μm). Incident irradiation is adjusted for I_L = 200 μA.

b. The output waveform is monitored on a oscillocope with the following characteristics: $t_r \leqslant$ 2.5 ns, R_{in} = 50 Ω.

FIGURE 1–SWITCHING TIMES

TYPICAL CHARACTERISTICS

DARK CURRENT
vs
CASE TEMPERATURE

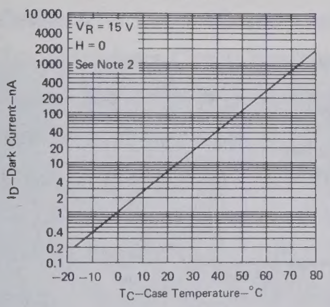


FIGURE 2

REVERSE CURRENT
vs
REVERSE VOLTAGE

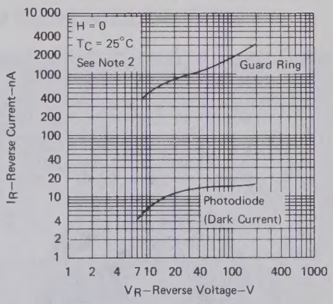


FIGURE 3

CAPACITANCE
vs
REVERSE VOLTAGE

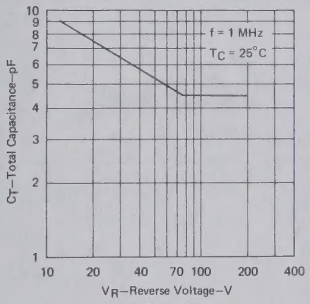


FIGURE 4

RESPONSIVITY
vs
WAVELENGTH

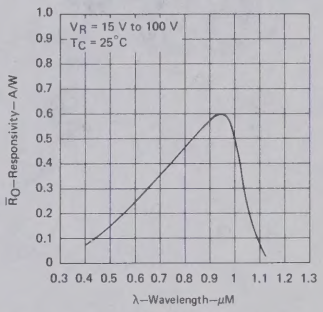


FIGURE 5

QUANTUM EFFICIENCY
vs
CASE TEMPERATURE

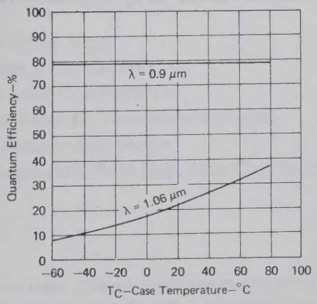


FIGURE 6

RISE AND FALL TIMES
vs
REVERSE VOLTAGE

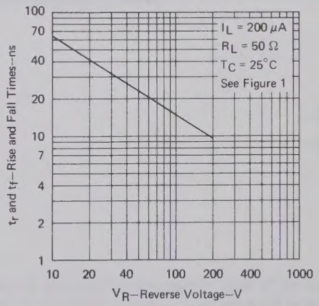


FIGURE 7

NOTE 2: Irradiance (H) is the radiant power per unit area upon a surface. Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

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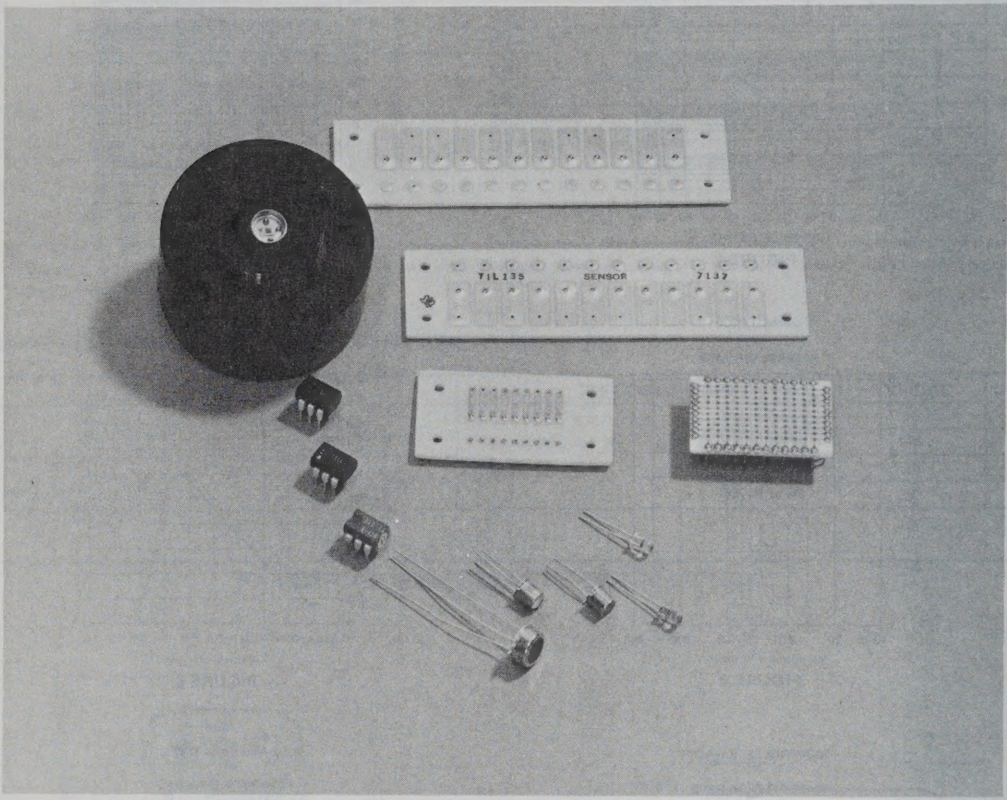

TIL135
SENSOR
7137

TYPES TIXL151, TIXL152
LOW-NOISE HIGH-SPEED TRANSIMPEDANCE AMPLIFIER

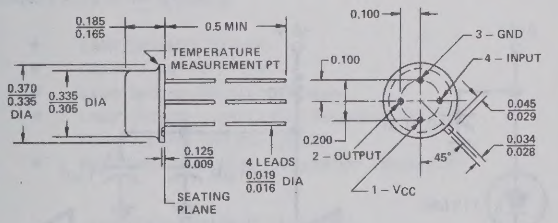
TYPES TIXL151, TIXL152
BULLETIN NO. DL-S7211690, MARCH 1972

OPTOELECTRONIC INTERFACE CIRCUIT
FOR IMPROVED SENSITIVITY IN APPLICATIONS SUCH AS LASER RANGEFINDERS AND OPTICAL COMMUNICATIONS

- Designed for Current Sources such as Photodiodes and Photomultiplier Tubes
- Transimpedance Circuit Provides Output Voltage Linearly Proportional to Input Current
- Typical Broadband Responses of 50 MHz and 18 MHz
- Typical Equivalent Input Noise Currents of 4.5 pA/$\sqrt{\text{Hz}}$ and 3 pA/$\sqrt{\text{Hz}}$†
- Low Input Impedance for Tolerance of High Source Capacitance
- Low Output Impedance for Loads as Small as 50 Ohms‡
- Single Supply of 4 to 6 Volts

mechanical data

The device is in a hermetically sealed welded case similar to but shorter than JEDEC TO-12. All TO-12 registration notes also apply to this outline.



LEAD 3 IS IN ELECTRICAL CONTACT WITH THE CASE

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Supply Voltage V_{CC}	8 V
Continuous Input Current	2 mA
External Load Conductance	20 mmho‡
Operating Free-Air Temperature Range	–55°C to 125°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

---

† Equivalent input noise current is defined as broadband rms output voltage divided by Z_F and by the square root of noise bandwidth. The noise bandwidth is $\pi/2$ times the signal bandwidth measured between the frequencies at which response is down 3 dB with a high-frequency rolloff of 6 dB/octave.

‡ Capacitive coupling is required for load resistances smaller than 1000 ohms.

TENTATIVE DATA SHEET

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

TYPES TIXL151, TIXL152
LOW-NOISE HIGH-SPEED TRANSIMPEDANCE AMPLIFIER

electrical characteristics at 25°C free-air temperature

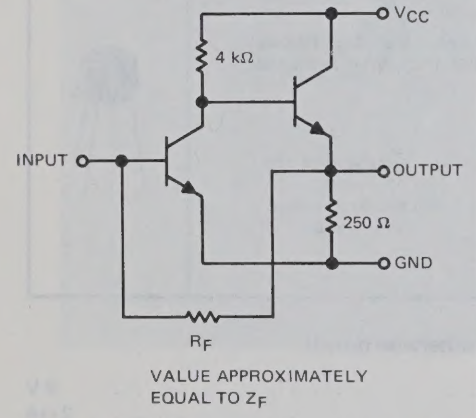
PARAMETER		TEST CONDITIONS§		TIXL151			TIXL152			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
I_n	Equivalent Input Noise Current†	R_L = 50 Ω,	See Note 1		4.5	7		3	5.5	pA/√Hz
Z_F	Forward Transfer Impedance	R_L = 50 Ω,	f = 20 kHz	2.8	4		8	12		kΩ
Z_I	Input Impedance	R_L = 50 Ω,	f = 20 kHz		100	140		300	500	Ω
Z_O	Output Impedance	I_{in} = 0,	f = 20 kHz		2	10		4	12	Ω
B	Bandwidth (−3 dB)	R_L = 50 Ω		40	50		12	18		MHz
I_{CC}	Supply Current	Input Open			4	6		4	7	mA

†Equivalent input noise current is defined as broadband rms output voltage divided by Z_F and by the square root of noise bandwidth. The noise bandwidth is π/2 times the signal bandwidth measured between the frequencies at which response is down 3 dB with a high-frequency rolloff of 6 dB/octave.

§V_{CC} = 5.5 V, output coupling capacitance = 1 μF, V_{CC} bypass capacitance = 0.01 μF.

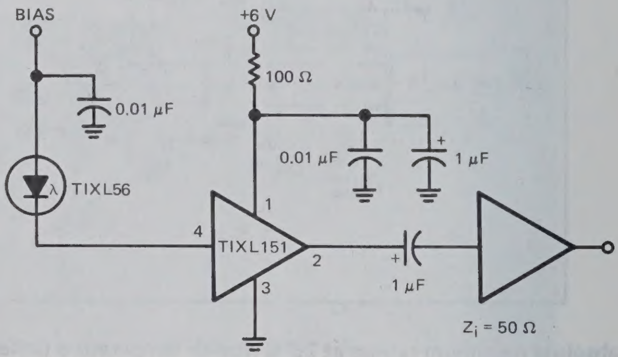
NOTE 1: Equivalent input noise current is determined using a post amplifier with response down 3 dB at 10 kHz and 150 MHz. Therefore, the overall signal bandwidth is equal to the bandwidth of the device under test.

schematic



Resistor values shown are nominal

typical application



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SILICON PHOTOAMPERIC DETECTORS

Texas Instruments Photoamperic silicon detectors provide outstanding performance in the visible and near-infrared portions of the electromagnetic spectrum. The term Photoamperic describes a photodiode operating under a large reverse bias. These detectors are usually large area, high-resistivity and high-speed silicon photodiodes. The principal advantages of these detectors, over standard silicon photodiodes, are

- Higher Speed (3 ns rise time at a reverse bias of 150 V).
- Better Spectral Response at 1.06 μm.
- Larger Output Signal
- Lower Optical System Costs

The principal applications for these Photoamperic detectors include the following:

- Laser Guidance Systems
- Optical Proximity Fuzes
- Laser Distance-Measuring Systems
- Laser Detection and Optical Alignment in Long Range Optical Communications
- High-Speed Character Recognition Equipment

PHOTOAMPERIC SILICON DETECTOR STRUCTURE

The basic structure of the Photoamperic silicon detector is shown in Figure 1. These are planar diffused diodes with an N+ guard-ring that are operated in a reverse-bias mode. The outstanding features of the detector structure are the following:

- High reliability due to silicon-nitride-passivated planar-diffused junction.
- High signal-to-noise output ratio due to low leakage current as a result of N+ guard ring, large area and anti-reflection coating on the detector element.
- Lower optical system costs as a result of large areas. Active areas up to 0.675-inch diameter are available.
- Ease of use as the detector operates at room temperature.
- Flexibility in system design. Single and multiple detector elements (0.009-inch distance between adjacent elements) in custom designed packages and in standard TO-5 and TO-18 outline packages are available.
- Higher speed as a result of low capacitance and high drift velocity due to large field formed by reverse-bias mode of operation.
- Better spectral response at 1.06 μm, when compared to standard photodiodes, due to higher quantum efficiencies at this wavelength as a result of the reverse-bias operation.

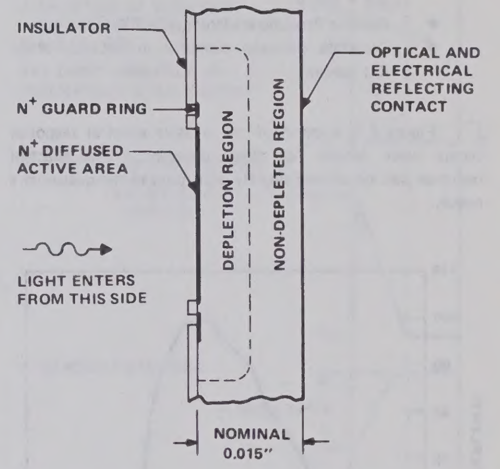

INSULATOR
N$^+$ GUARD RING
N$^+$ DIFFUSED ACTIVE AREA
LIGHT ENTERS FROM THIS SIDE
DEPLETION REGION
NON-DEPLETED REGION
OPTICAL AND ELECTRICAL REFLECTING CONTACT
NOMINAL 0.015"

FIGURE 1. Basic Structure of the Photoamperic Silicon Detector

ELECTRICAL CHARACTERISTICS:

Typical detector electrical characteristics at 300°K detector temperature are:

- Quantum Efficiency (300°K background and 2870°K blackbody signal source and at a reverse bias of 150 V)
  - > 60 percent at 1.06 μm

  - > 70 percent at 0.90 μm
  - > 60 percent at 0.60 μm
  - > 30 percent at 0.40 μm
- Rise and Fall Time ⩽ 3 ns (each) at V_R = 150 V, where V_R is the reverse-bias voltage.
- Capacitance < 35 pF/cm² at V_R = 150 V
- Reverse Leakage Current < 1 μA/cm² at V_R = 150 V.
- Reverse Breakdown Voltage > 300 V.
- Crosstalk between elements in detector array < 1 percent.

Figure 2 is a graph of the relative spectral response versus wave length for these detectors. This spectral response can be altered slightly according to the customer's needs.

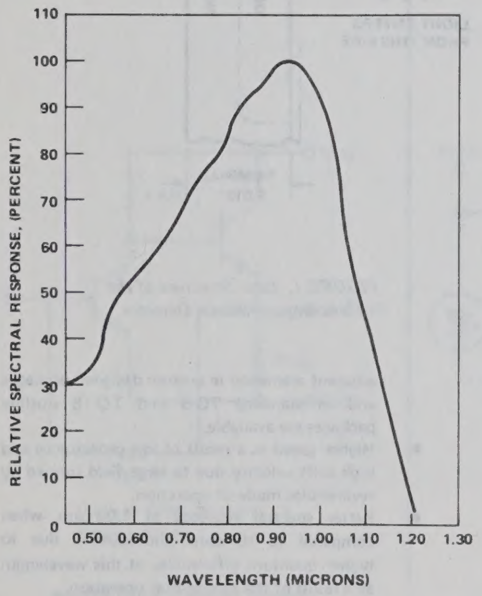


FIGURE 2. Relative Spectral Response Curve

A plot of the typical leakage current at various reverse-bias levels is shown in Figure 3. Figure 4 is a plot of leakage current per cm² versus temperature for a partially depleted detector. These two graphs illustrate the basic noise considerations for the detector.

A capacitance versus reverse-bias voltage plot of a partially and a fully depleted detector is shown in Figure 5. Note that the fully depleted detector capacitance becomes independent of the voltage once the detector is fully depleted.

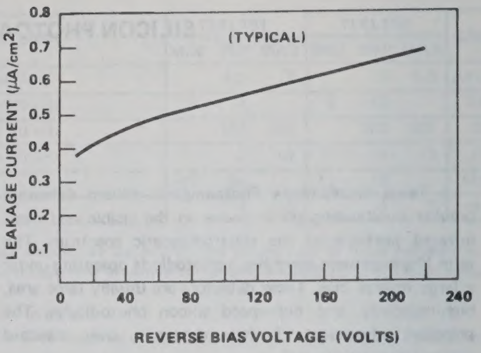


FIGURE 3. Leakage Current versus Reverse Bias Voltage

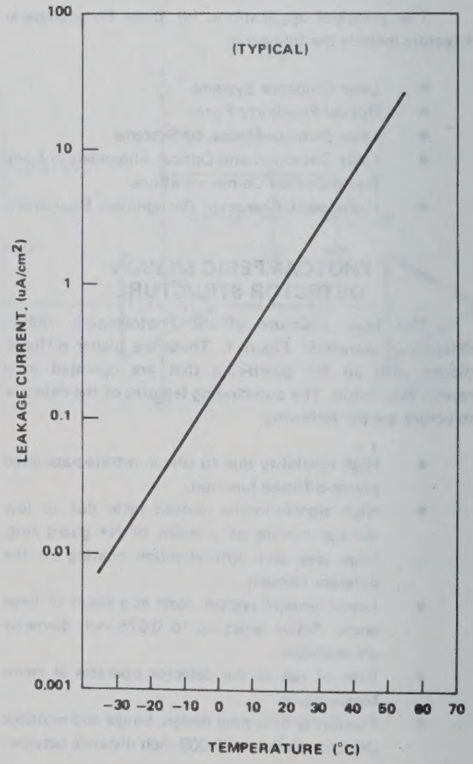


FIGURE 4. Reverse Leakage Current versus Temperature

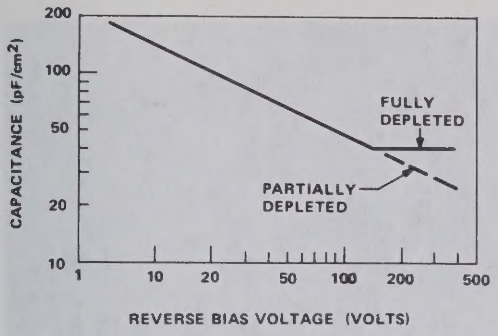


FIGURE 5. Capacitance versus Reverse Bias Voltage

PHOTOAMPERIC DETECTOR OPERATION:

The basic operation of a partially depleted photodetector is illustrated with the help of Figure 6. When the reverse-bias is applied to the detector, the depletion region expands and a high field is formed within the detector. The electron-hole pairs which are created in this depletion region by the incoming electromagnetic radiation have a high drift velocity which results in their fast and efficient collection. At a constant reverse bias, the depletion region width is proportional to the square root of the resistivity of the silicon material. The large depletion region of the Photoamperic detector results in a low capacitance. The wide depletion region in combination with the absorption characteristics of silicon leads to high quantum efficiency at wavelengths greater than 0.9 μm.

The basic electrical model for these detectors operated under a reverse bias is shown in Figure 7.

Texas Instruments is currently engaged in the volume production of these detectors (Figure 8) to military specifications and is actively pursuing various development programs for both commercial and military applications. Texas Instruments produces its own high resistivity silicon (greater than 10,000 ohm-cm) and is delivering devices manufactured from this material.

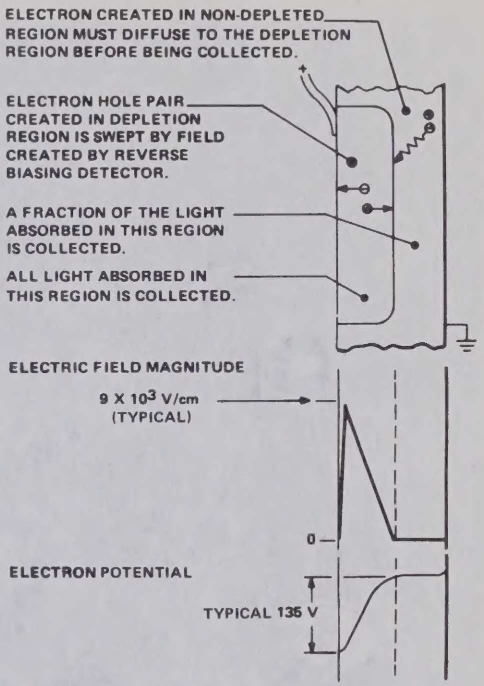
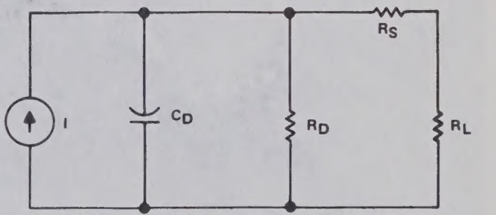

ELECTRON CREATED IN NON-DEPLETED REGION MUST DIFFUSE TO THE DEPLETION REGION BEFORE BEING COLLECTED.
ELECTRON HOLE PAIR CREATED IN DEPLETION REGION IS SWEPT BY FIELD CREATED BY REVERSE BIASING DETECTOR.
A FRACTION OF THE LIGHT ABSORBED IN THIS REGION IS COLLECTED.
ALL LIGHT ABSORBED IN THIS REGION IS COLLECTED.
+
ELECTRIC FIELD MAGNITUDE
9 X 10^3 V/cm (TYPICAL)
0
ELECTRON POTENTIAL
TYPICAL 135 V

FIGURE 6. Basic Operation of the Photoamperic Detector



where I = photoelectric current generated,
C_D = detector capacitance
R_D = detector impedance,
R_S = detector series resistance, and
R_L = load resistor.

FIGURE 7. Basic Electrical Model for the Photoamperic Detector Operating in Reverse-Bias Mode

The generated current I, in amperes is given by

$$I = 0.8\,\eta\lambda PA$$

where η = quantum efficiency,
λ = wavelength of operation in microns,
P = power of incident radiation in watts/cm^2, and
A = junction area in cm^2.

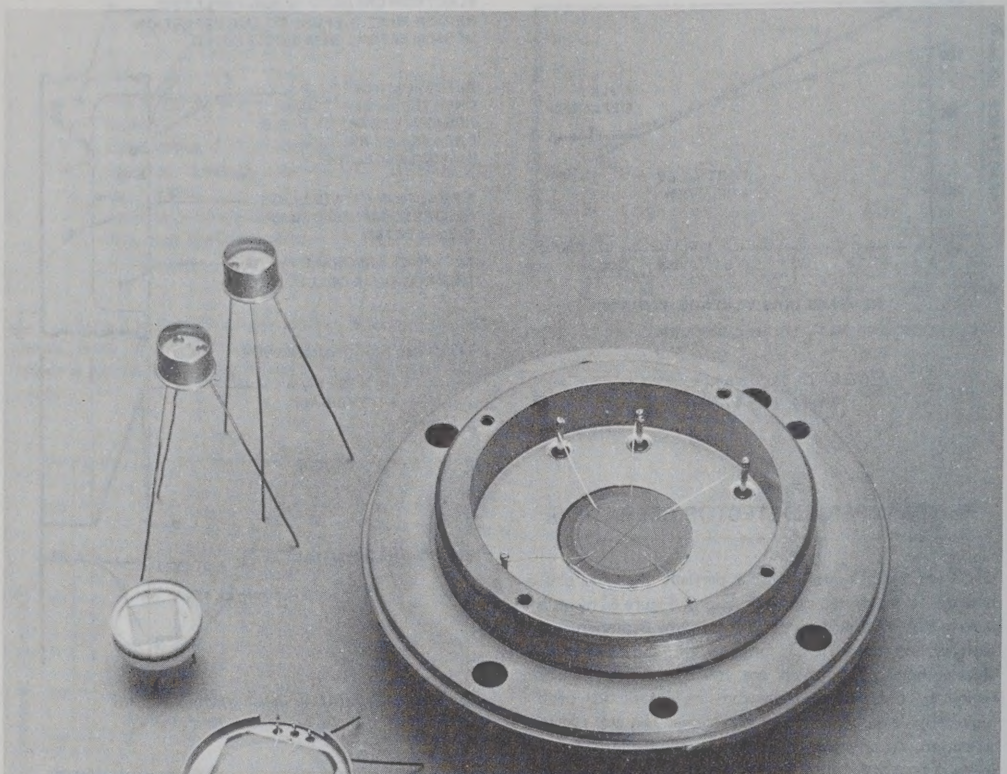


FIGURE 8. Photoamperic Silicon Detectors from Texas Instruments

Infrared Emitters

QUICK REFERENCE GUIDE
INFRARED EMITTERS

INFRARED EMITTERS
QUICK REFERENCE GUIDE

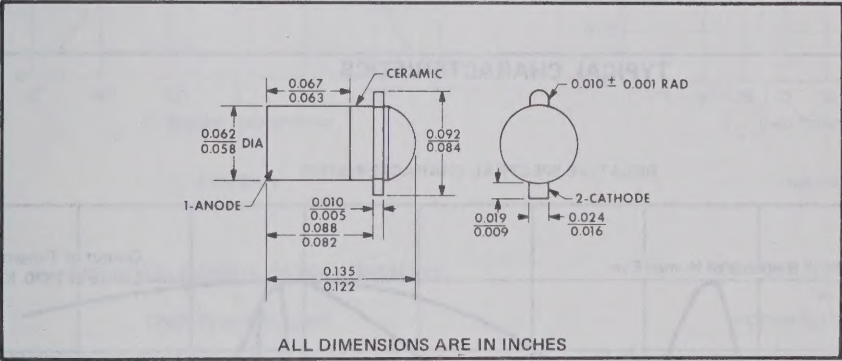
DEVICE	PKG	POWER OUTPUT		θ_{HP}	V_F		λ_P	FEATURES
		MIN @ mW	I_F mA	TYP	MAX @ V	I_F mA	TYP μm	
TIL23	4 A	0.4	50	35°	1.5	50	0.93	Pill package for mounting on double-sided printed circuit board
TIL24	4 A	1	50	35°	1.5	50	0.93	
TIL31	4 D	3.3	100	10°	1.75	100	0.94	Hermetically sealed TO-18 package.
TIL32	5 J	0.5	20	35°	1.6	20	0.94	Low-cost plastic package
TIXL06	4 F	0.6	500	115°	2.3	500	0.91	0.0075-inch-dia flat emitting area
TIXL12	4 F	40	300	130°	2	300	0.93	0.036-inch-dia hemispherical dome emitting area
TIXL13	4 F	20	300	130°	2	300	0.93	
TIXL14	4 F	60	1000	130°	2	1000	0.93	0.072-inch-dia hemispherical dome emitting area
TIXL15	4 F	30	1000	130°	2	1000	0.93	
TIXL16	4 N	200	2000	150°	2	2000	0.93	0.072-inch-dia dome emitter
TIXL19	4 O	10	200		2	200	0.85	Spectrally matched to silicon sensors and photoemissive sensors
TIXL20	4 O	5	200		2	200	0.82	
TIXL21	4 P	10	200		2	200	0.85	
TIXL22	4 P	5	200		2	200	0.82	
TIXL26	3 Y	1	35	175°	1.9	35	0.93	Low-cost header with epoxy lens
TIXL27	5 Q	15	300	135°	2.2	300	0.94	Stud header with epoxy lens

TYPES TIL23, TIL24
BULLETIN NO. DL-S 7011312, FEBRUARY 1970

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

- Output Spectrally Compatible with Silicon Sensors
- High Power Efficiency, Typically 1.5 Percent at 25°C
- High Power Output, Typically 2.0 mW at 25°C
- Small Size Permits Matrix Assembly Directly into Printed Circuit Boards
- High Radiant Intensity, Typically 7 mW/sr for TIL24

mechanical data


CERAMIC
0.067
0.063
0.062
0.058 DIA
0.092
0.084
1-ANODE
0.010
0.005
0.088
0.082
0.135
0.122
0.010 ± 0.001 RAD
2-CATHODE
0.019
0.009
0.024
0.016
ALL DIMENSIONS ARE IN INCHES

4 TIMES
ACTUAL SIZE

absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Continuous Forward Current at 25°C Case Temperature (See Note 1)	100 mA
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (3 Minutes)	240°C

[†] Radiant intensity is calculated from $I = P_O/2\pi(1-\cos 0.5_{HP})$. One steradian is the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere.

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mA/°C. For pulsed operation at higher currents, see Figures 8 and 9.

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIL23			TIL24			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
P_O	Radiant Power Output	I_F = 50 mA	0.4			1			mW
λ_p	Wavelength at Peak Emission			0.93			0.93		μm
B	Spectral Bandwidth between Half-Power Points			500			500		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			35°			35°		
V_F	Static Forward Voltage			1.25	1.5			1.5	V

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

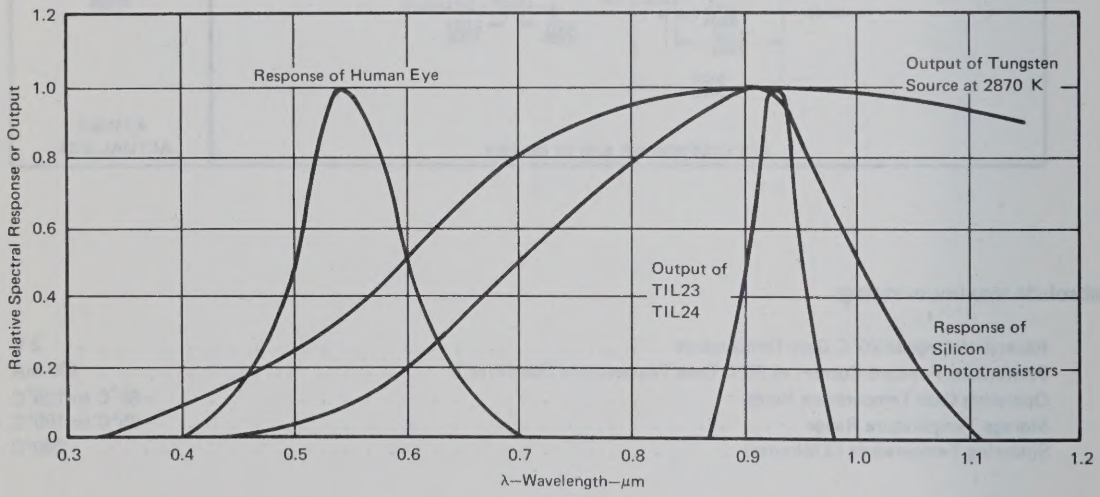


FIGURE 1

TYPICAL CHARACTERISTICS

RELATIVE PHOTON INTENSITY
vs
ANGULAR DISPLACEMENT

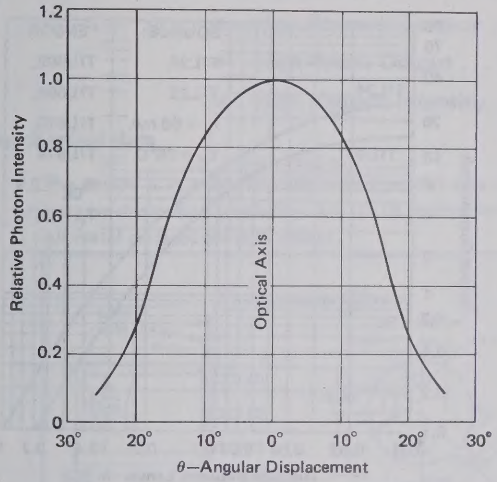


FIGURE 2

RELATIVE POWER OUTPUT
vs
CASE TEMPERATURE

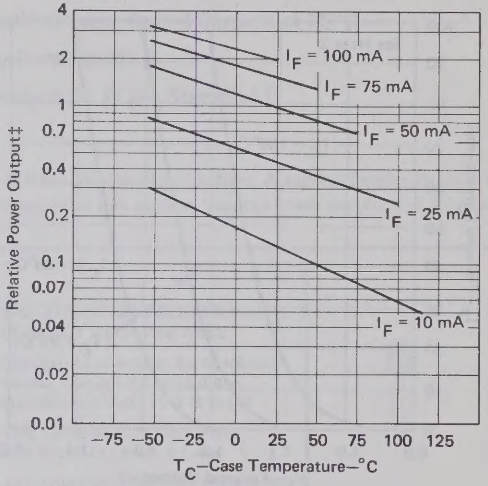


FIGURE 3

CHANGE IN WAVELENGTH OF PEAK INTENSITY
vs
CASE TEMPERATURE

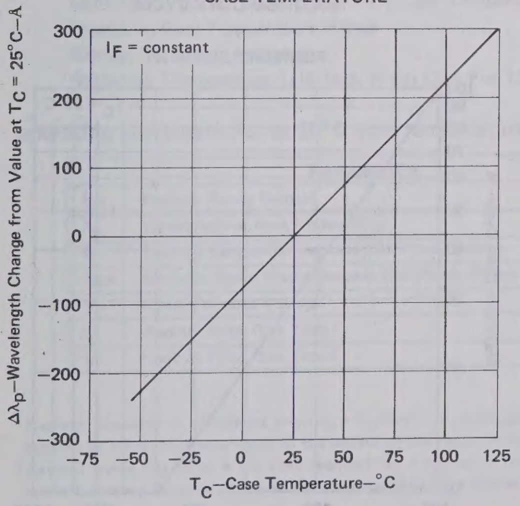


FIGURE 4

RELATIVE POWER OUTPUT
vs
FORWARD CURRENT

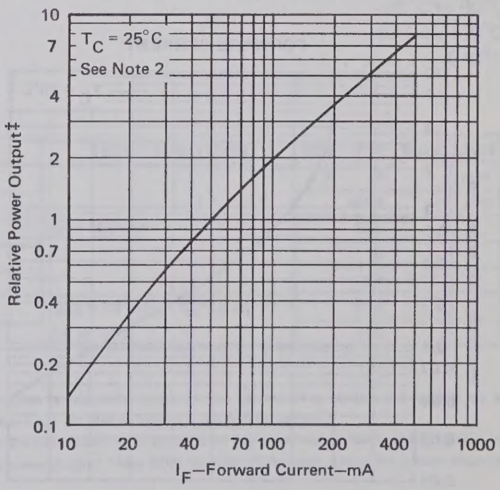
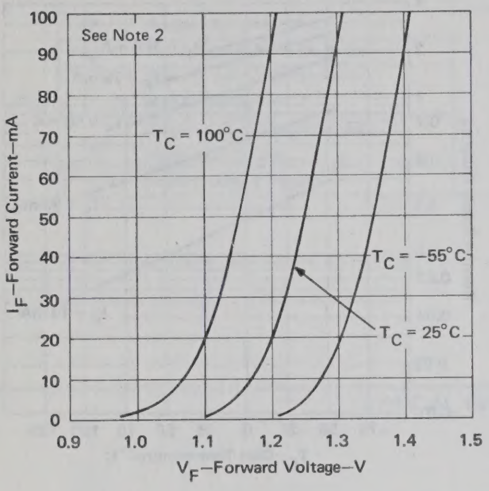


FIGURE 5

NOTE 2: These parameters must be measured using pulse techniques: t_w = 0.04 ms, duty cycle ≤ 10%.
‡Normalized to output at I_F = 50 mA, T_C = 25°C.

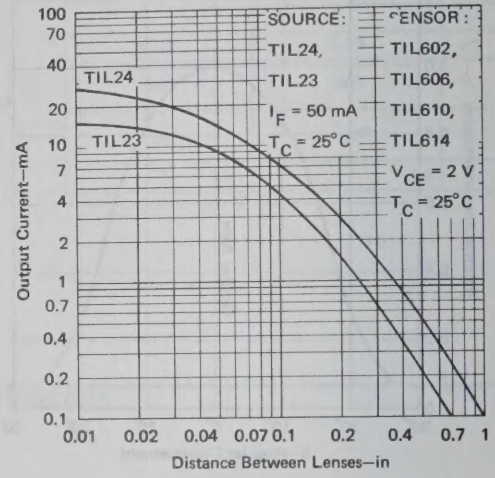
TYPICAL CHARACTERISTICS



TIL23

FORWARD CONDUCTION CHARACTERISTICS

FIGURE 6

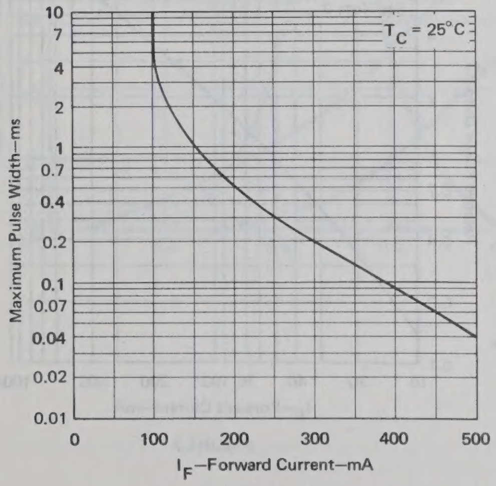


COUPLING CHARACTERISTICS OF TIL23 AND TIL24 WITH TIL602, TIL606, TIL610, OR TIL614

FIGURE 7

NOTE 2: These parameters must be measured using pulse techniques: t_w = 0.04 ms, duty cycle ≤ 10%.

THERMAL CHARACTERISTICS

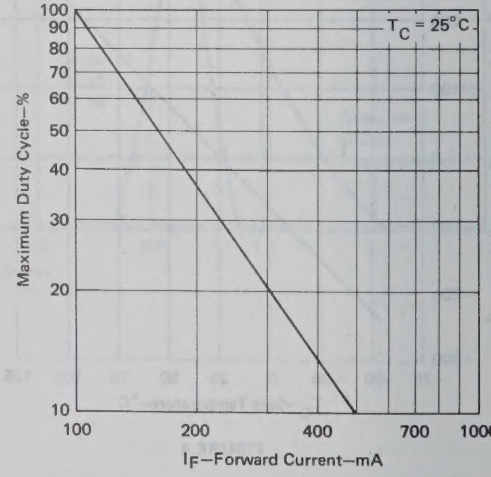


MAXIMUM PULSE WIDTH

vs

FORWARD CURRENT

FIGURE 8



MAXIMUM DUTY CYCLE

vs

FORWARD CURRENT

FIGURE 9

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

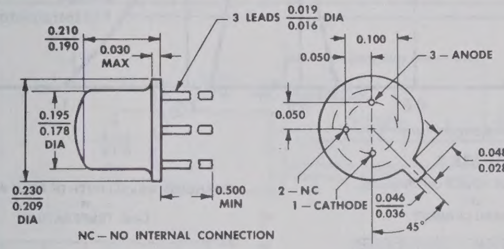
TYPE TIL31
P-N GALLIUM ARSENIDE LIGHT SOURCE

DESIGNED TO EMIT
NEAR-INFRARED LIGHT
WHEN FORWARD BIASED

- Output Spectrally Compatible with Silicon Sensors
- High Power Efficiency . . . Typically Greater than 4 Percent at 25°C
- High Power Output . . . Typically 6 mW at 25°C
- High Radiant Intensity . . . Typically 0.25 W per Steradian†

mechanical data

The device is in a hermetically sealed welded case similar to JEDEC TO-18 with window. A coined header is used to increase dissipation capability. All TO-18 registration notes also apply to this outline. Approximate weight is 0.35 gram. All metal surfaces are gold plated.



THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.040, MINIMUM DIAMETER IS 0.140

THE LENS IS CORNING 7052 (OR EQUIVALENT) GLASS

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Continuous Forward Current at 25°C Case Temperature (See Note 1)	200 mA
Operating Case Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Soldering Temperature 1/16 Inch From Case For 10 Seconds	240°C

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 100 mA	3.3	6		mW
λ_p	Wavelength at Peak Emission			0.94		µm
B	Spectral Bandwidth between Half-Power Points			600		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			10°		
V_F	Static Forward Voltage			1.4	1.75	V
t_r	Radiant Pulse Rise Time‡	I_{FM} = 50 mA, t_w = 2 µs, f = 45 kHz		600		ns
t_f	Radiant Pulse Rise Time‡			350		

---

†Radiant intensity is calculated from $I_e = P_O/2\pi(1-\cos 0.5\theta_{HP})$. One steradian is the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere.

‡Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current; radiant pulse fall time is the time required for a change in radiant power output from 90% to 10% of its peak value for a step change in current.

NOTE 1: Derate linearly to 80°C case temperature at the rate of 3.6 mA/°C.

TYPE TIL31
P-N GALLIUM ARSENIDE LIGHT SOURCE

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

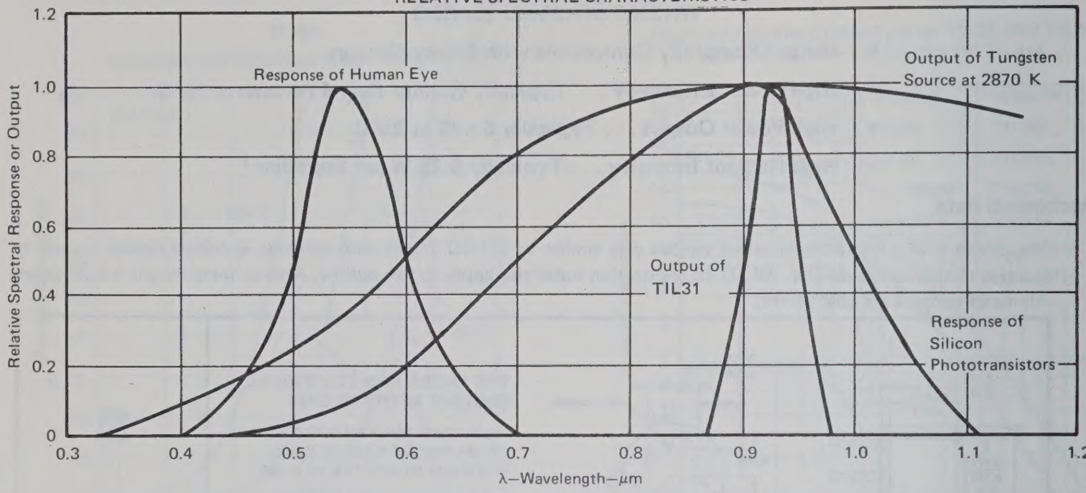


FIGURE 1

RELATIVE POWER OUTPUT vs CASE TEMPERATURE

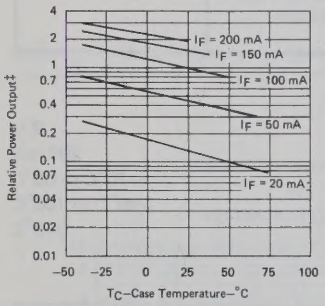


FIGURE 2

RELATIVE POWER OUTPUT vs FORWARD CURRENT

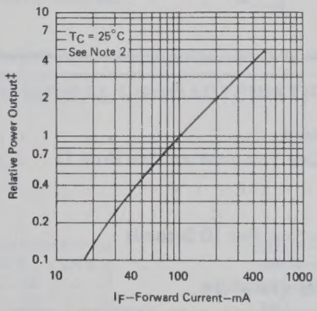


FIGURE 3

CHANGE IN WAVELENGTH OF PEAK INTENSITY vs CASE TEMPERATURE

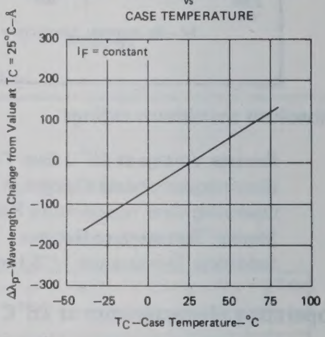


FIGURE 4

RELATIVE PHOTON INTENSITY vs ANGULAR DISPLACEMENT

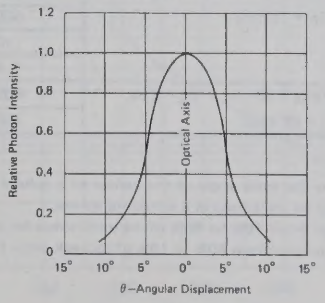


FIGURE 5

FORWARD CONDUCTION CHARACTERISTICS

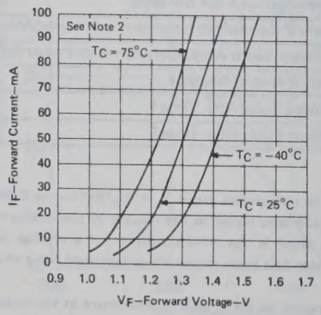


FIGURE 6

NOTE 2: This parameter must be measured using pulse techniques. t_w = 0.04 ms, duty cycle ⩽ 10%.

‡Normalized to output at I_F = 10 mA, T_C = 25°C.

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P-N GALLIUM ARSENIDE LIGHT SOURCE

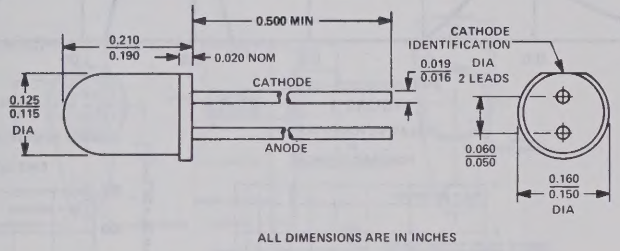
TYPE TIL32
BULLETIN NO. DL-S 7111542, SEPTEMBER 1971

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

- Output Spectrally Compatible with Silicon Sensors
- High Power Efficiency . . . Typically 5 Percent at 25°C
- High Power Output . . . Typically 1.2 mW at 25°C
- High Radiant Intensity . . . Typically 4 mW per Steradian†
- Plastic Package with Two Leads for Ease of Handling

mechanical data

This device has a clear molded epoxy body with silver-plated dumet leads.



ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	40 mA
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	240°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 20 mA	0.5	1.2		mW
λ_p	Wavelength at Peak Emission			0.94		μm
B	Spectral Bandwidth between Half-Power Points			600		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			35°		
V_F	Static Forward Voltage			1.2	1.6	V
t_r	Radiation Pulse Rise Time‡	I_{FM} = 20 mA, t_w = 2 μs, f = 45 kHz		600		ns
t_f	Radiation Pulse Rise Time‡			350		

† Radiant intensity is calculated from $I_e = P_O/2\pi(1-\cos 0.5\theta_{HP})$. One steradian is the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere.

‡ Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current; radiant pulse fall time is the time required for a change in radiant power output from 90% to 10% of its peak value for a step change in current.

NOTE 1: Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

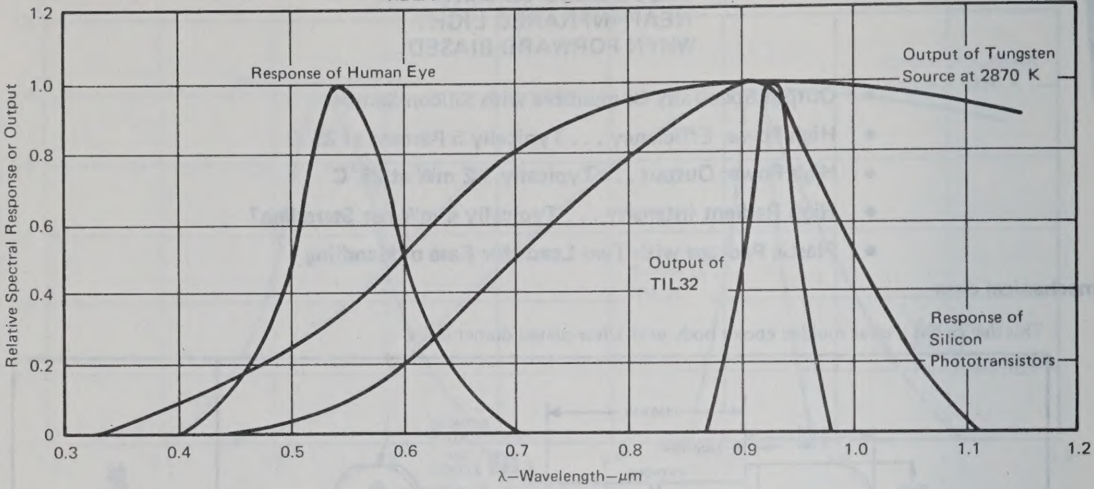


FIGURE 1

RELATIVE POWER OUTPUT vs FREE-AIR TEMPERATURE

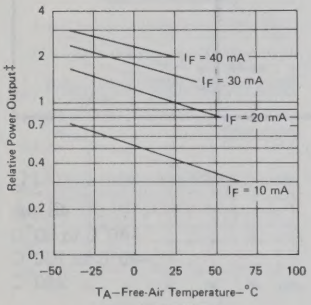


FIGURE 2

RELATIVE POWER OUTPUT vs FORWARD CURRENT

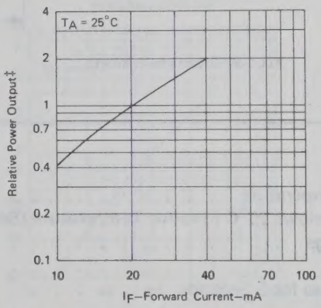


FIGURE 3

CHANGE IN WAVELENGTH OF PEAK INTENSITY vs FREE-AIR TEMPERATURE

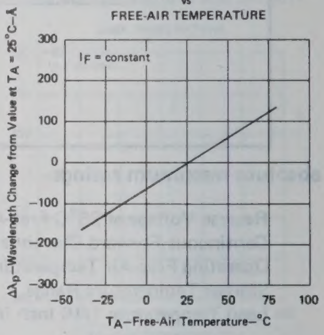


FIGURE 4

RELATIVE PHOTON INTENSITY vs ANGULAR DISPLACEMENT

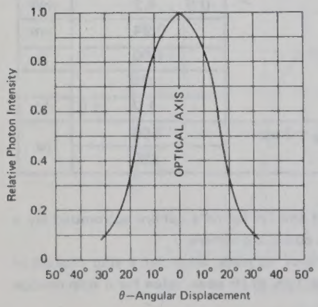


FIGURE 5

COUPLING CHARACTERISTICS OF TIL32 WITH TIL78

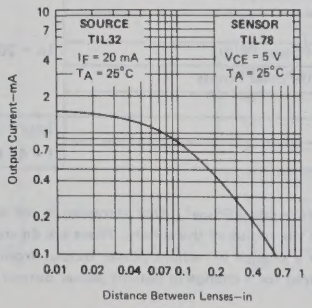


FIGURE 6

FORWARD CONDUCTION CHARACTERISTICS

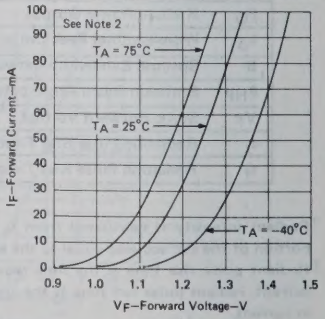


FIGURE 7

NOTE 2: This parameter must be measured using pulse techniques: t_w = 0.04 ms, duty cycle ⩽ 10%.

‡Normalized to Output at I_F = 20 mA, T_A = 25°C.

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME
IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE

TYPE TIXL06
P-N PLANAR GALLIUM ARSENIDE DIODE LIGHT SOURCE

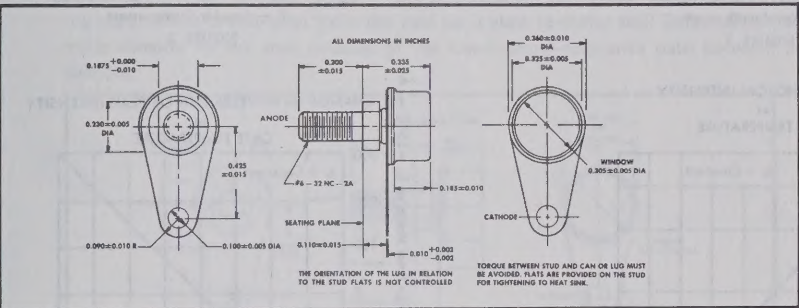
TYPE TIXL06
BULLETIN NO. DL-S 729723, FEBRUARY 1967
REVISED FEBRUARY 1972

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

- Light source spectrally matched to silicon sensors
- High brightness
- Circular, consistent-size, flat emitting areas . . . 7.5 mils diameter
- Recommended for precision optical alignment, communication, and photographic film annotation
- Formerly the PEX1004

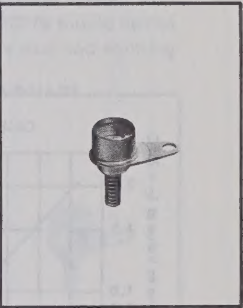
mechanical data

This device is in a hermetically sealed package with a flat glass window in the top of the case. The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal.


ALL DIMENSIONS IN INCHES
0.1875 +0.000 −0.010
0.230±0.005 DIA
0.425 ±0.015
0.090±0.010 R
0.100±0.005 DIA
0.300 ±0.015
0.335 ±0.025
ANODE
#6 – 32 NC – 2A
0.185±0.010
SEATING PLANE
0.110±0.015
0.010 +0.003 −0.002
0.360±0.010 DIA
0.325±0.005 DIA
WINDOW 0.305±0.005 DIA
CATHODE

THE ORIENTATION OF THE LUG IN RELATION TO THE STUD FLATS IS NOT CONTROLLED

TORQUE BETWEEN STUD AND CAN OR LUG MUST BE AVOIDED. FLATS ARE PROVIDED ON THE STUD FOR TIGHTENING TO HEAT SINK.



absolute maximum ratings

Reverse Voltage at 25°C Case Temperature . . . . 2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1) . . . . 500 mA
Storage Temperature Range . . . . −55°C to 125°C
Solder Lug Temperature for 10 Seconds (See Note 2) . . . . 240°C

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 500 mA	0.6	1.2		mW
λ_P	Wavelength at Peak Emission			0.91		μm
B	Spectral Bandwidth between Half-Power Points			250		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			115°		
V_F	Static Forward Voltage			1.7	2.3	V

NOTES: 1. Derate linearly to 125°C case temperature at the rate of 5 mA/°C.
2. Soldered connections should not be made directly to the stud because of the low-resistance path between the stud and emitting element.

TYPICAL CHARACTERISTICS

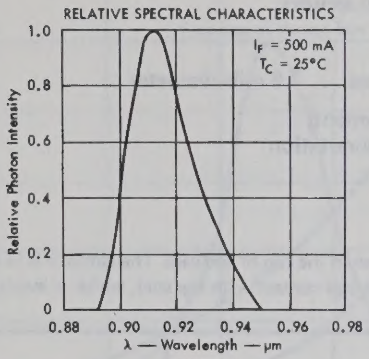


FIGURE 1

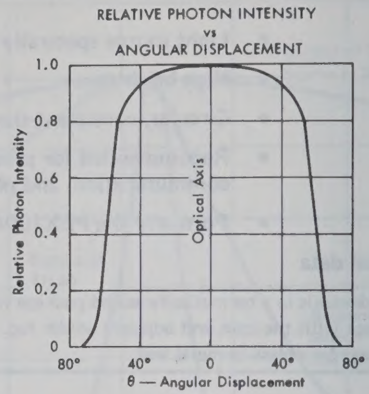


FIGURE 2

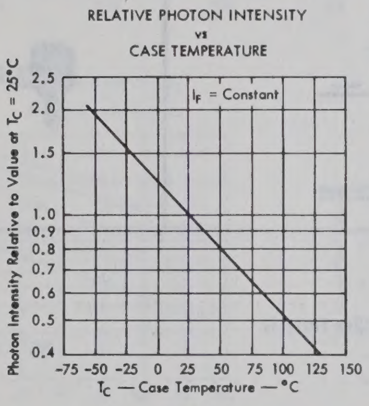


FIGURE 3

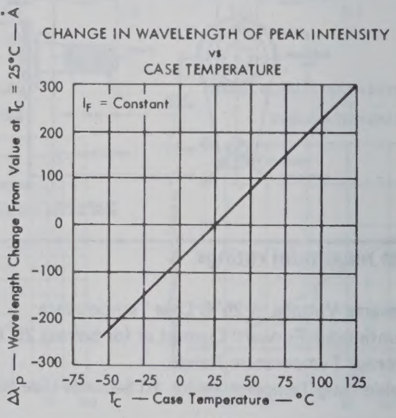


FIGURE 4

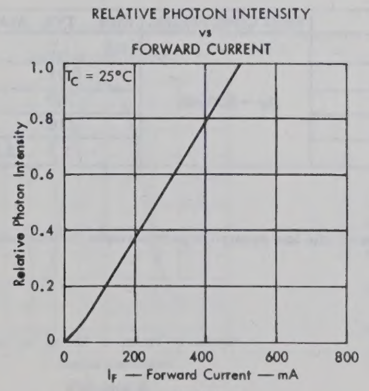


FIGURE 5

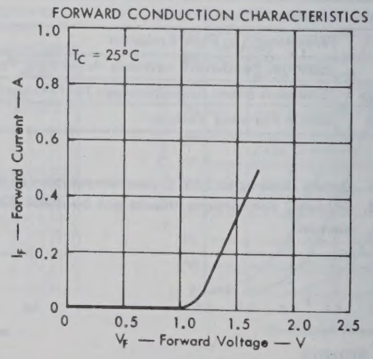


FIGURE 6

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

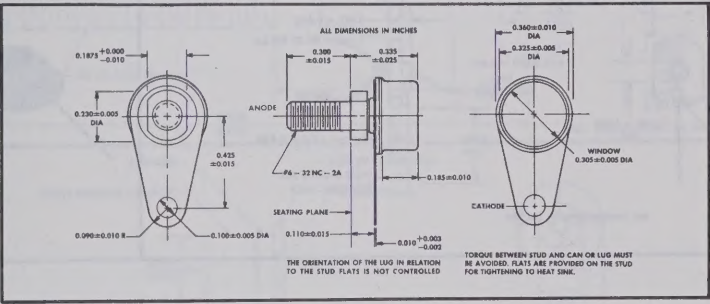
TIXL12, TIXL13, TIXL14, TIXL15
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCES

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

- High Output . . . 60 mW min at 25°C for the TIXL14
- High Output Efficiency . . . 10% min at 25°C for TIXL12
- Hemispherical Emitting Crystals with Diameters of 36 mils for the TIXL12 and TIXL13, 72 mils for the TIXL14 and TIXL15
- Spectrally Matched to Silicon Sensors
- Stud-Mounted Package for Convenient Mounting and Heat Sinking
- Formerly PEX1203/OSX1203, PEX1205/OSX1205, PEX1206/OSX1206, PEX1207/OSX1207, Respectively

mechanical data

The devices are in hermetically sealed packages with a flat glass window in the top of the case. The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between the stud and emitting element.



THE ORIENTATION OF THE LUG IN RELATION TO THE STUD FLATS IS NOT CONTROLLED

TORQUE BETWEEN STUD AND CAN OR LUG MUST BE AVOIDED. FLATS ARE PROVIDED ON THE STUD FOR TIGHTENING TO HEAT SINK.

absolute maximum ratings

	TIXL12 TIXL13	TIXL14 TIXL15
Reverse Voltage at 25°C Case Temperature	2 V	2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1)	300 mA	1 A
Storage Temperature Range	−55°C to 100°C	
Solder Lug Temperature for 10 Seconds	←240°C→	

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	TIXL12 and TIXL13: I_F = 300 mA TIXL14 and TIXL15: I_F = 1 A	TIXL12	40			mW
			TIXL13	20			
			TIXL14	60			
			TIXL15	30			
λ_p	Wavelength at Peak Emission		All		0.93		μm
B	Spectral Bandwidth between Half-Power Points		All		450		Å
θ_{HP}	Emission Beam Angle between Half-Power Points		All		130°		
V_F	Static Forward Voltage		All		1.4	2	V

NOTE: 1. Derate linearly to 100°C case temperature at the rate of 4 mA/deg for the TIXL12 and TIXL13, 13.3 mA/deg for the TIXL14 and TIXL15.

PRELIMINARY DATA SHEET: Supplementary data may be published at a later date.

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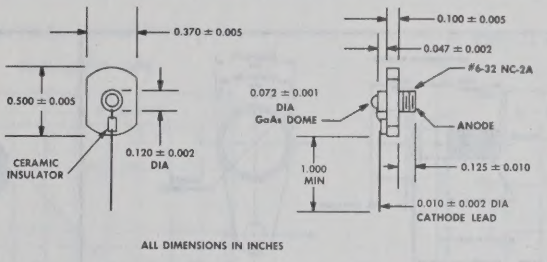
TYPE TIXL16
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCE

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

- **High Output Power . . . 200 mW Min at 25°C**
- **Hemispherical Emitter with a Diameter of 72 mils**
- **Stud Mounting for Convenient Heat Sinking**
- **Open Construction to Allow Flexibility in Optical Design**
- **Formerly PEX1208/OSX1208**

mechanical data

The diode is mounted on a copper stud header to provide efficient heat sinking. The anode is in electrical contact with the copper stud. The cathode lead is a varnished 0.01-inch copper wire secured to the stud by a metalized ceramic insulator. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path to the emitting element.



absolute maximum ratings

Reverse Voltage at 25°C Stud Temperature . . . . 2 V
Continuous Forward Current at (or below) 25°C Stud Temperature (See Note 1) . . . . 2 A
Storage Temperature Range . . . . -55°C to 100°C
Lead Temperature ¼ Inch from Ceramic Insulator for 5 Seconds . . . . 230°C

operating characteristics at 25°C stud temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_o	Radiant Power Output	$I_F = 2$ A	200			mW
λ_p	Wavelength at Peak Emission			0.93		μm
B	Spectral Bandwidth between Half-Power Points			450		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			150°		
V_F	Static Forward Voltage			1.6	2	V

NOTE: 1. Derate linearly to 100°C stud temperature at the rate of 26.6 mA/deg.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

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TYPE TIXL19 THRU TIXL22
P-N PLANAR GALLIUM ARSENIDE PHOSPHIDE DIODE LIGHT SOURCES

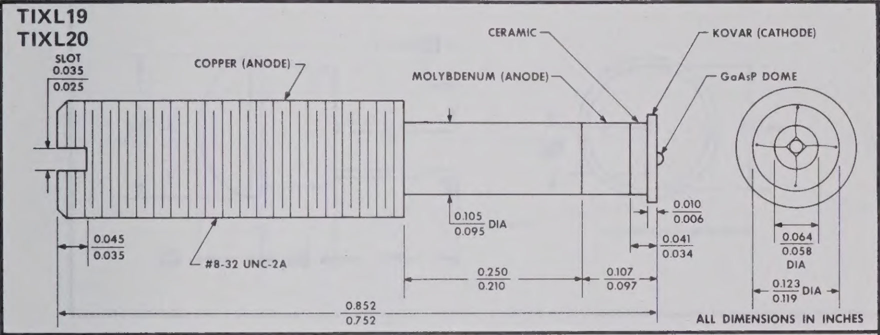
TYPE TIXL19 THRU TIXL22
BULLETIN NO. DL-S 691293, DECEMBER 1969

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

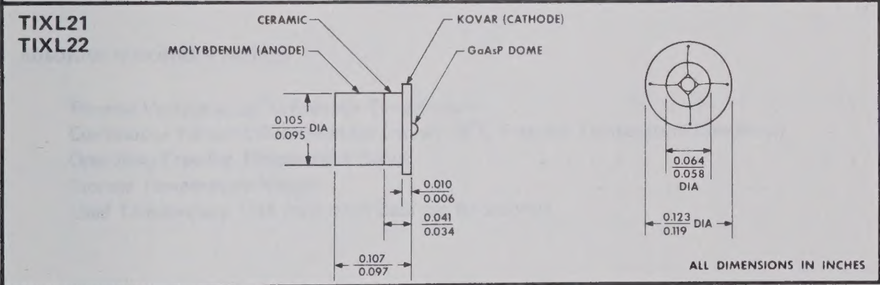
Spectrally Matched to Silicon Sensors and Photoemissive Sensors, such as S-1 and S-20

mechanical data

The emitting surface of the GaAsP material is hemispherical. The cathode is in electrical contact with the top flange and the anode is in electrical contact with the base plug.


TIXL19
TIXL20
SLOT
0.035
0.025
COPPER (ANODE)
CERAMIC
MOLYBDENUM (ANODE)
KOVAR (CATHODE)
GaAsP DOME
0.010
0.006
0.105
0.095
DIA
0.045
0.035
#8-32 UNC-2A
0.041
0.034
0.064
0.058
DIA
0.250
0.210
0.107
0.097
0.123
0.119
DIA
0.852
0.752
ALL DIMENSIONS IN INCHES

ACTUAL SIZE


TIXL21
TIXL22
CERAMIC
MOLYBDENUM (ANODE)
KOVAR (CATHODE)
GaAsP DOME
0.105
0.095
DIA
0.010
0.006
0.041
0.034
0.107
0.097
0.064
0.058
DIA
0.123
0.119
DIA
ALL DIMENSIONS IN INCHES

FOUR TIMES ACTUAL SIZE

absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1)	200 mA
Storage Temperature Range	−65°C to 100°C
Soldering Temperature (3 Seconds)	240°C

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIXL19, TIXL21			TIXL20, TIXL22			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
P_o	Radiant Power Output	I_F = 200 mA	10			5			mW
λ_p	Wavelength at Peak Emission			0.85			0.82		μm
B	Spectral Bandwidth Between Half-Power Points			250			250		Å
V_F	Static Forward Voltage		1.5	1.7	2	1.5	1.7	2	V

NOTE: 1. Derate linearly to 100°C case temperature at the rate of 2.67 mA/°C.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

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INFRARED EMITTER INTERFACE CHART

The following TI devices are commonly used in circuits for interfacing with infrared emitters. This interface chart is intended to be used for reference only since each circuit design is unique.

DEVICE TYPE	DESCRIPTION	USED WITH
2N4300	N-P-N Epitaxial Planar Silicon Power Transistor	Laser Diodes
2N5385	P-N-P Epitaxial Planar Silicon Power Transistor	Laser Diodes
2N5450	N-P-N Epitaxial Planar Silicon Transistor	Infrared Emitters
TIP33	N-P-N Single-Diffused Silicon Power Transistor	Infrared Emitters

TYPE TIXL26
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCE

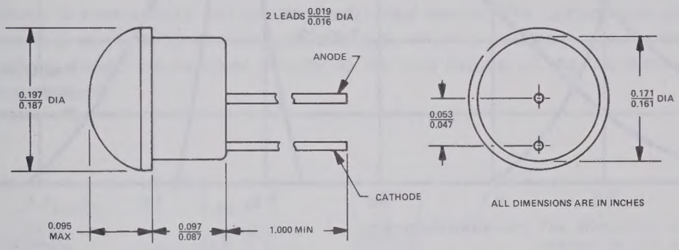
TYPE TIXL26
BULLETIN NO. DL-S 7111574, SEPTEMBER 1971

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

- Spectrally Matched to Silicon Sensors
- Typical Applications Include Card Readers, Encoders, and Intrusion Alarms

mechanical data

BOTH LEADS ELECTRICALLY INSULATED FROM CASE


2 LEADS $\frac{0.019}{0.016}$ DIA
ANODE
$\frac{0.197}{0.187}$ DIA
CATHODE
0.095 MAX
$\frac{0.097}{0.087}$
1.000 MIN
$\frac{0.053}{0.047}$
$\frac{0.171}{0.161}$ DIA

ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note)	50 mA
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 35 mA	1			mW
λ_p	Wavelength at Peak Emission			0.93		µm
B	Spectral Bandwidth between Half-Power Points			500		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			175°		
V_F	Static Forward Voltage			1.2	1.9	V

NOTE: Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.

TENTATIVE DATA SHEET
This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

TYPE TIXL26
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCE

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

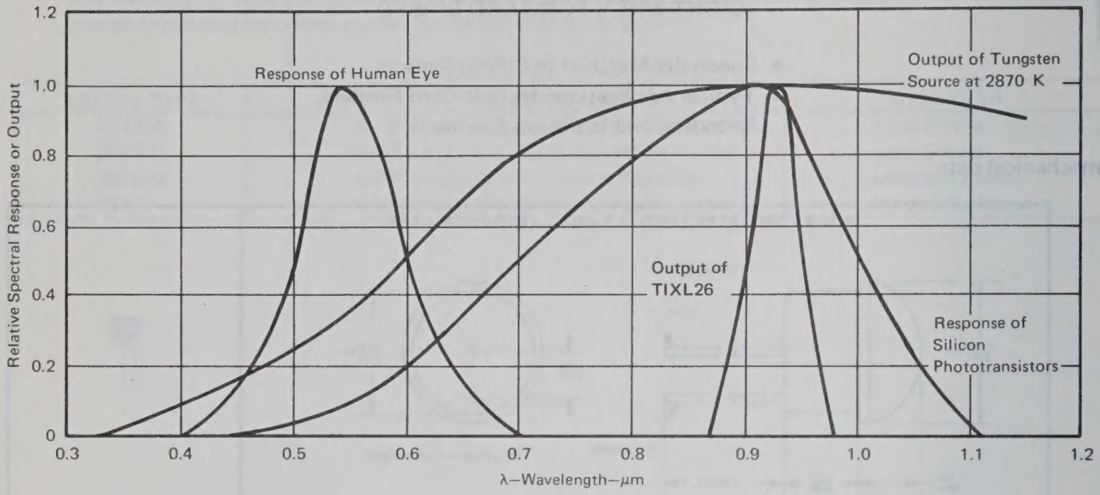


FIGURE 1

FORWARD CONDUCTION CHARACTERISTICS

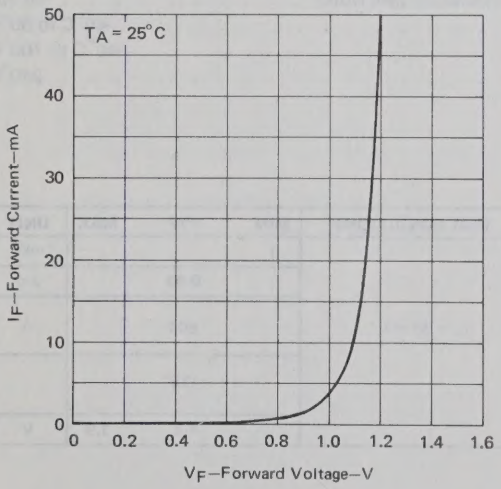


FIGURE 2

RELATIVE POWER OUTPUT
vs
FORWARD CURRENT

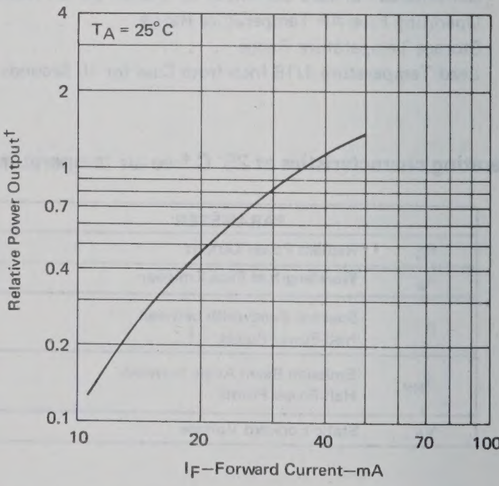


FIGURE 3

†This curve normalized to output at I$_F$ = 35 mA, T$_A$ = 25°C.

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TYPE TIXL27
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCE

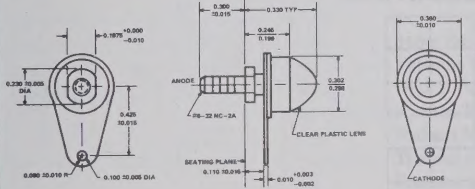
TYPE TIXL27
BULLETIN NO. DL-S 7111566, SEPTEMBER 1971

DESIGNED TO EMIT NEAR-INFRARED LIGHT WHEN FORWARD BIASED

- High Output Power . . . 15 mW Min at 25°C
- Spectrally Matched to Silicon Sensors
- Stud Mounting for Convenient Heat Sinking
- Recommended for Precision Optical Alignment, Industrial Controls, and Optical Communications

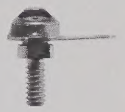
mechanical data

The device is encapsulated and mounted on a stud header. The cathode is in electrical contact with the solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between stud and emitting element.



NOTES: A. The orientation of the lug in relation to the stud flats is not controlled.
B. Torque between stud and lug must be avoided. Flats are provided on the stud for tightening to heat sink.

ALL DIMENSIONS IN INCHES



absolute maximum ratings

Reverse Voltage at 25°C Stud Temperature	2 V
Continuous Forward Current at (or below) 25°C Stud Temperature (See Note 1)	300 mA
Operating Stud Temperature Range	0°C to 70°C
Storage Temperature Range	−50°C to 90°C
Solder Lug Temperature for 10 Seconds	240°C

operating characteristics at 25°C stud temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 300 mA	15	20		mW
λ_p	Wavelength at Peak Emission			0.94		μm
B	Spectral Bandwidth between Half-Power Points			450		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			135°		
V_F	Static Forward Voltage			1.7	2.2	V

NOTE 1: Derate linearly to 70°C stud temperature at the rate of 6.7 mA/°C.

TENTATIVE DATA SHEET
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TYPE TIXL27
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCE

TYPICAL CHARACTERISTICS

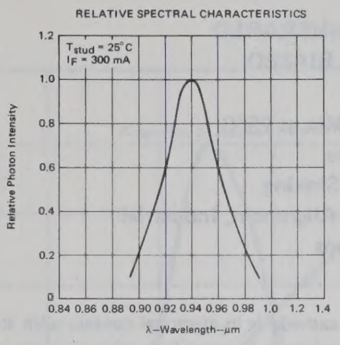

FIGURE 1

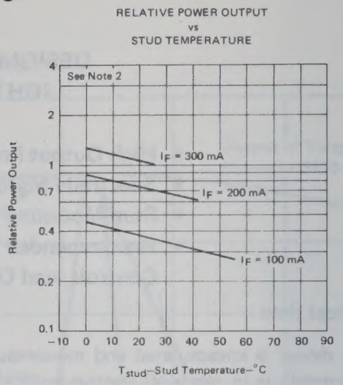

FIGURE 2

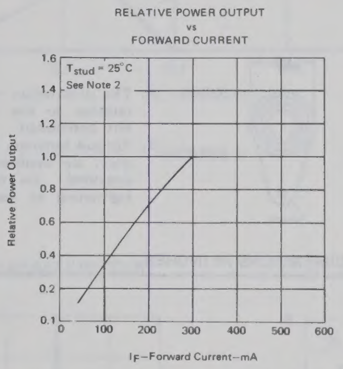

FIGURE 3

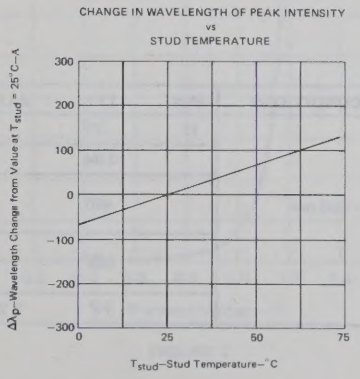

FIGURE 4

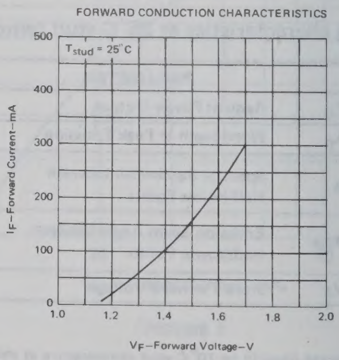

FIGURE 5

NOTE 2: These curves have been normalized to the output at I_F = 300 mA, T_{stud} = 25°C.

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EFFICIENT HIGH-POWER GaAs EMITTERS

Larry D. Major and Ronald D. Grotti

The Gallium Arsenide (GaAs) hemispherical emitter is a solution-grown light emitting diode (LED). It offers the highest optical power available in spontaneous light emitters, together with increased light quanta efficiency. The outputs of the TIXL12- TIXL16 series of LEDs range from 20 mW to 200 mW at their respective forward bias currents.

These infrared emitters are capable of meeting applicable Mil-Std tests, and find applications in optical communications.

This report presents basic information necessary to fully utilize these high optical power output and high efficiency infrared emitters.

Topics discussed include:

Theory of Operation

Device Performance

- Series Resistance
- Forward Voltage
- Optical Power
- Spectral Distribution
- Radiant Intensity
- Thermal Impedance
- Frequency Response

Package Configuration and Design

Typical GaAs Emitter Circuits

THEORY OF OPERATION

The GaAs spontaneous light emitter is essentially a solution-grown P-N junction isolated by mesa formation in the shape of 36 mil and 72 mil diameter hemispheres.

Its theory of operation is similar to silicon and germanium emitters. In each case the P-type and the N-type regions are formed in a single crystal.

When the P-N junction is forward biased, electrons from the N region are injected into the P region and light quanta (photons) are generated through recombination. This light energy is emitted in the near-infrared region.

The hemispheric dome structure provides a substantial increase in light source quanta efficiency from that of flat geometry sources.

The light source quanta efficiency (η_s) is defined by the equation

$$\eta_S = \frac{q\,N_S}{I_f} \qquad (1)$$

where

N_S = the external photon rate
q = the electronic charge
I_f = the forward current

It is clear from equation (1) that any increase in N_s would mean an increase in efficiency.

When the ratio of the junction radius to the dome radius is equal to the sine of the critical angle, that is, when

$$\sin\theta_c = \frac{r_j}{R_o} \qquad (2)$$

where

r_j = the junction radius,
R_o = the dome radius, and
θ_c = critical angle,

all the light reaching the surface of the hemisphere will make an angle less than Θ_c with the normal to the surface.

Under these conditions total internal reflection is eliminated. The external photon rate (N_s) is maximized, increasing efficiency of the device.

DEVICE PERFORMANCE

SERIES RESISTANCE

The voltage-current characteristic, (Figures 1,2, and 3,) for a LED can be approximated by the following equation,

$$I = I_o\left(e^{\frac{qv}{nKT}} - 1\right) \qquad (3)$$

where

I = forward current
I_o = reverse saturation current
q = electron charge
v = applied voltage
K = Boltzmann constant
T = temperature

At normal operating conditions, $I \gg I_o$. Therefore differentiating equation (3) we get

$$\frac{dV}{dI} = \frac{nKT}{qI} \equiv r \qquad (4)$$

where

r = series resistance

From equation (4) it is obvious that r is a function of I. However over the normal operating region r can be approximated and considered constant. The value of r can be measured from the V-I characteristic. Table I shows values obtained from the V-I characteristics for the TIXL12-TIXL16 series.

Table I

SERIES RESISTANCE (T = 25°C)			
Device Type	Min r (Ω)	Typical r (Ω)	Max r (Ω)
TIXL 12, 13	0.75	0.90	1.05
TIXL 14, 15, 16	0.13	0.17	0.21

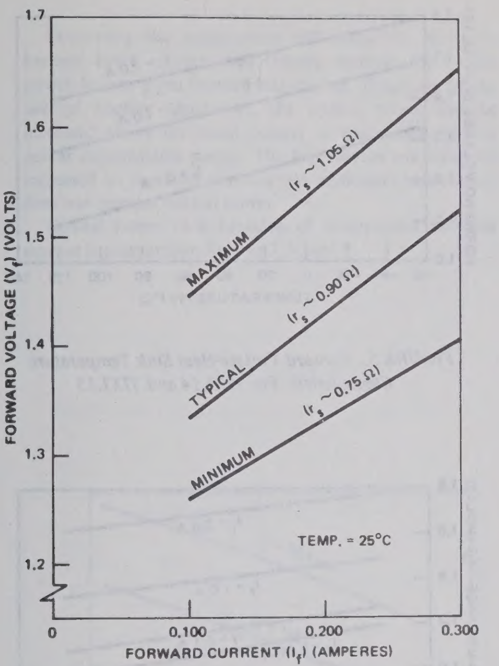


FIGURE 1. Forward Voltage-Forward Current Characteristics For TIXL12 and TIXL13

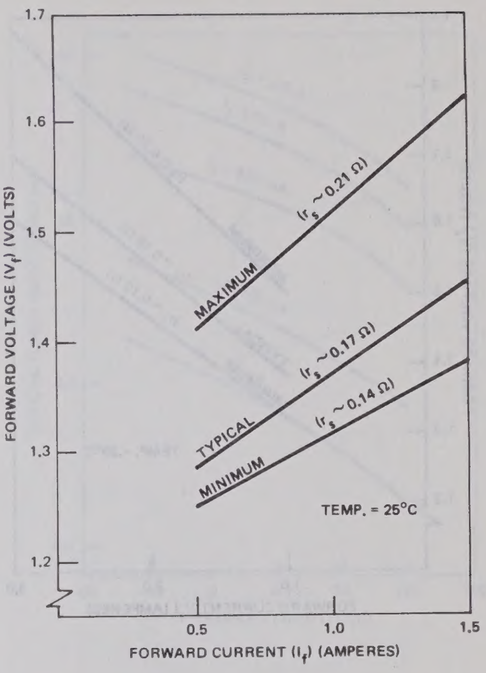


FIGURE 2. Forward Voltage-Forward Current Characteristics For TIXL14 and TIXL15

FORWARD VOLTAGE

The GaAs LEDs exhibit forward voltage-temperature dependence values lower than accepted values for silicon.

The value of dV/dT is a function of current. Average values of dV/dT may be calculated from the forward voltage-temperature curves, Figures 4, 5, and 6.

Average values of dV/dT obtained from Figures 4, 5, and 6 are shown in Table II.

Table II

Device Type	ΔV/ΔT
TIXL 12, 13	−1.5 mV/°C
TIXL 14, 15, 16	−1.2 mV/°C

At constant temperature, voltage change as a function of current can be predicted from equation (3)

$$\Delta V_f = \frac{nKT}{q}\log_e\frac{I_{f1}}{I_{f2}} \qquad (5)$$

where

V_f = forward voltage
I_f = forward current
n = constant

The values of n range from 1 to 3 for GaAs LEDs. Exact values may be obtained by characterizing the diode under the operating conditions to which it will be exposed.

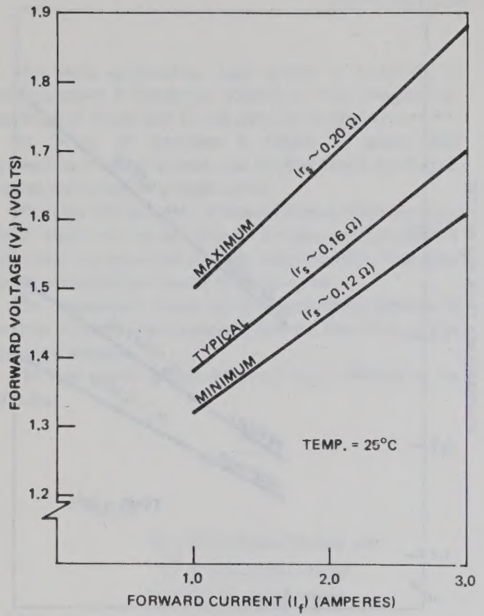


FIGURE 3. Forward Voltage-Forward Current Characteristics for TIXL16

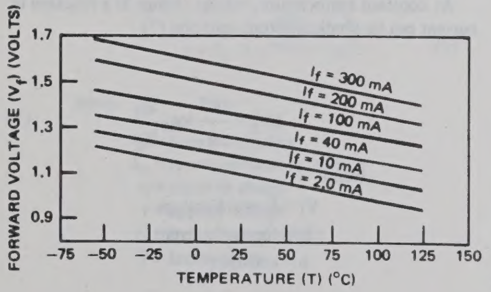


FIGURE 4. Forward Voltage-Heat Sink Temperature Characteristics For TIXL12 and TIXL13

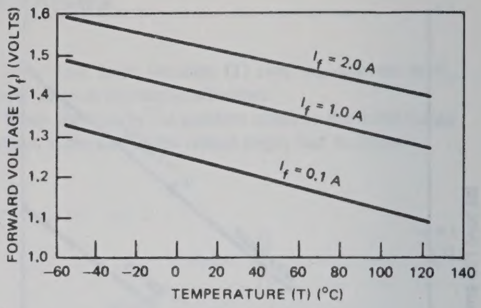


FIGURE 5. Forward Voltage-Heat Sink Temperature Characteristic For TIXL14 and TIXL15

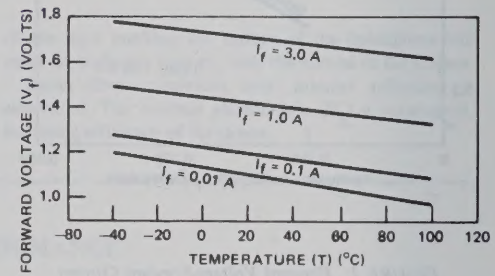


FIGURE 6. Forward Voltage-Heat Sink Temperature For TIXL16

OPTICAL POWER

The optical power generated by GaAs light emitters is nearly a linear function of the forward bias current when operated above very low currents and below the maximum rated current.

The optical power becomes more linear with the bias current as the temperature is decreased. Table III shows the observed $\Delta P/\Delta I$ in the linear operating region.

Table III

Device Type	ΔP/ΔI (mW/mA)
TIXL 12, 13	0.2
TIXL 14, 15	0.1
TIXL 16	0.15

Decreasing the temperature will cause the diode to become more efficient and thereby increase the optical power for any given forward bias current. Therefore, by the use of cooling equipment, the optical power can be increased above the rated powers, if space and external power requirements permit. The bias current can safely be increased to the level above which additional bias current does not increase optical power.

Optical power as a function of temperature and bias current is presented in Figures 7, 8, and 9.

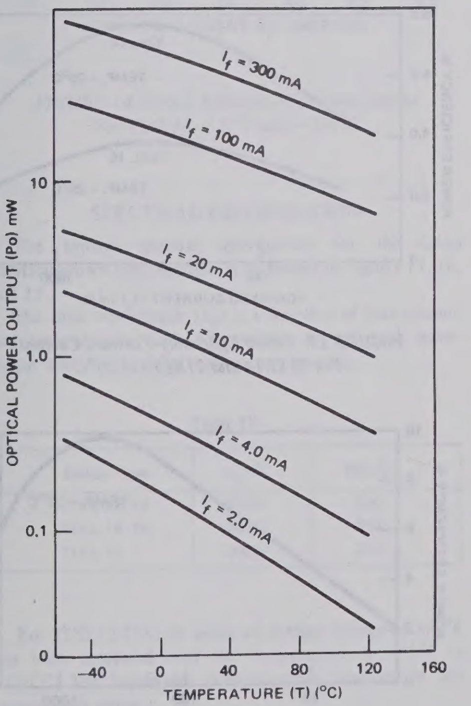


FIGURE 7. Optical Power Output-Heat Sink Temperature For TIXL12

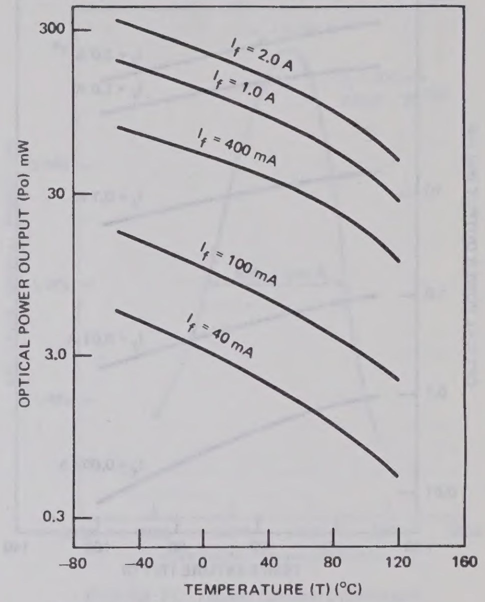


FIGURE 8. Optical Power Output-Heat Sink Temperature For TIXL14

An approximation that can be used when designing with LEDs is the optical power will increase by a factor of 2 when the temperature is decreased by 80°C. The optical power will decrease by 0.5 when the temperature is increased by 80°C. The reference of unity optical power is the optical power observed at 25°C.

The TIXL16 has been operated at liquid nitrogen temperature (–196°C), and the observed optical power as a function of bias current is shown in Figure 10.

Power Efficiency: The power efficiency of GaAs LEDs is defined as the optical power divided by the input current-voltage product. The power efficiency is a function of current.

Figures 11, 12, and 13 present the power efficiency capabilities of the GaAs solution grown devices. Figure 14 presents the power efficiency of the TIXL16 at liquid nitrogen (–196°C).

The maximum value of the TIXL12-TIXL16 series is slightly below the maximum recommended bias current rating.

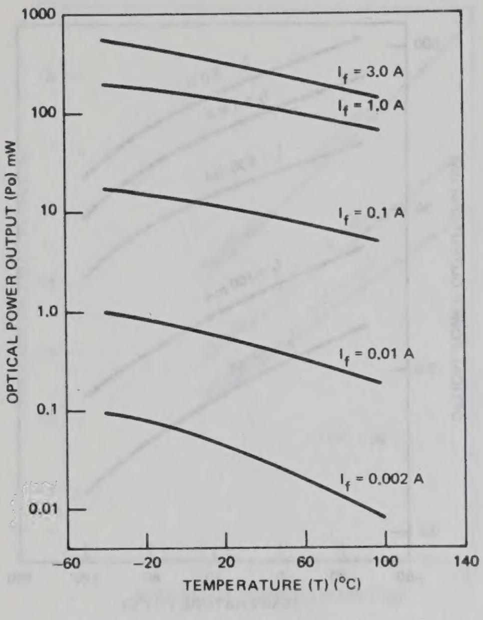


FIGURE 9. Optical Power Output-Heat Sink Temperature For TIXL16

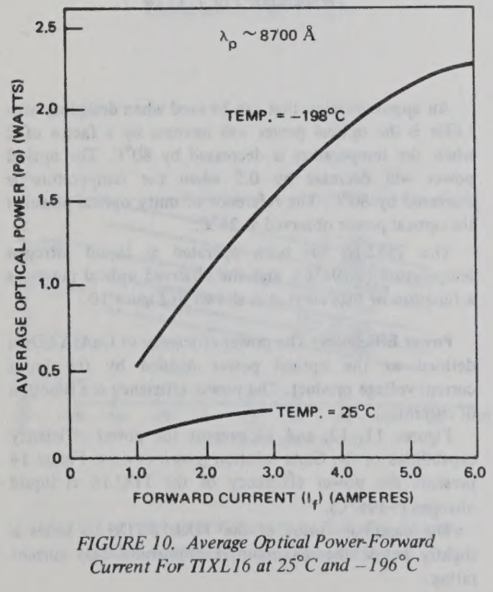


FIGURE 10. Average Optical Power-Forward Current For TIXL16 at 25°C and –196°C

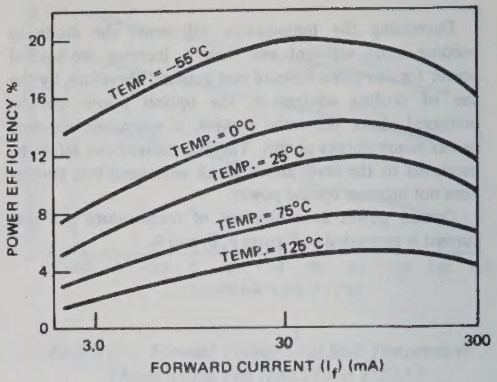


FIGURE 11. Power Efficiency-Forward Current For TIXL12

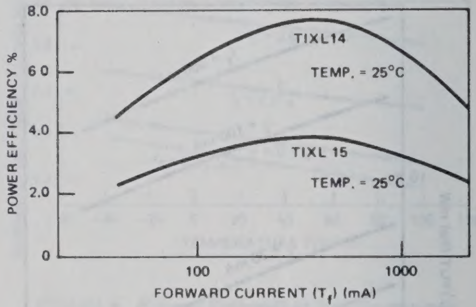


FIGURE 12. Power Efficiency-Forward Current For TIXL14 and TIXL15 at 25°C

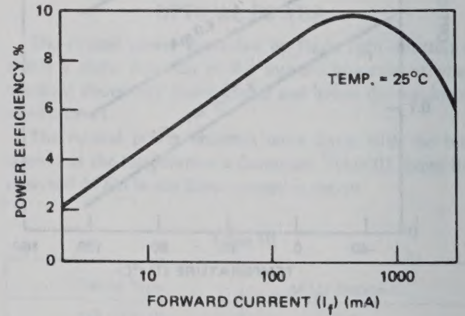


FIGURE 13. Power Efficiency-Forward Current For TIXL16 at 25°C

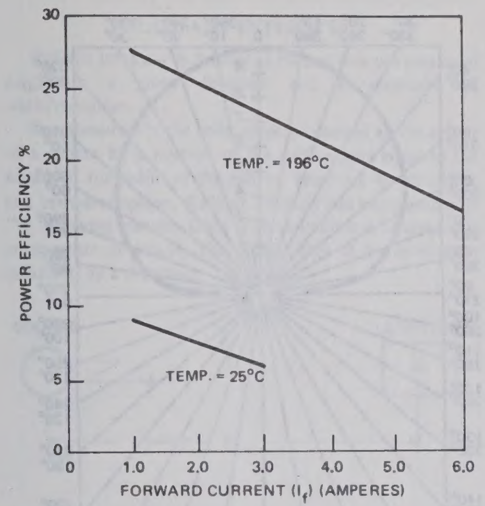


FIGURE 14. Power Efficiency-Forward Current For TIXL16 at 25°C and –196°C

SPECTRAL DISTRIBUTION

The typical spectral distribution for the GaAs solution-grown light emitters is presented in Figures 15, 16, and 17.

The peak wavelength (λ_p) is a function of bias current and temperature. Table IV presents typical peak wavelength and bandwidths (half power points).

Table IV

Device Type	λ_p Å	BW_θÅ
TIXL 12, 13	9300	350
TIXL 14, 15	9300	350
TIXL 16	9300	350

For TIXL12-TIXL16 series an average change of 3Å/°C has been measured over the temperature of –50°C to +120°C. The bandwidth remains nearly constant in this temperature range.

Relative Intensity: Polar plots of typical relative intensity versus angular displacement are presented in Figures 18 and 19. Figure 20 presents what a reflector can do in aiding the designer when a narrow beam is required.

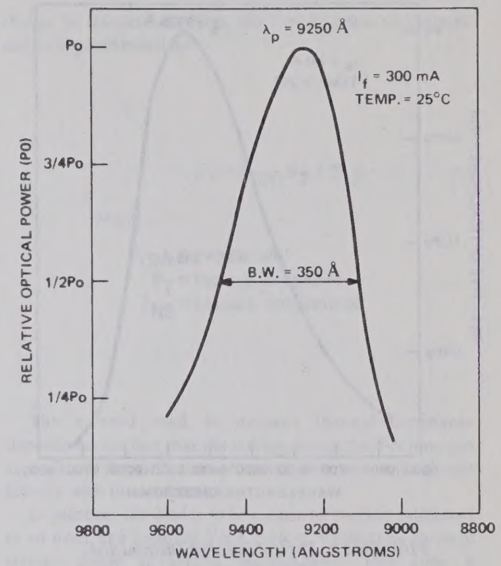


FIGURE 15. Typical Spectral Distribution For TIXL12

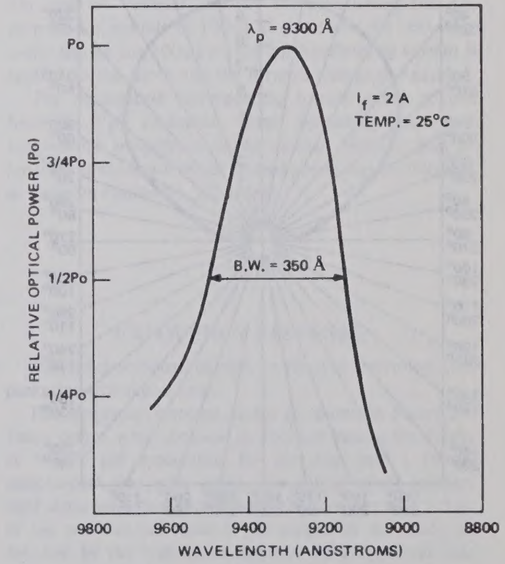


FIGURE 16. Typical Spectral Distribution For TIXL14

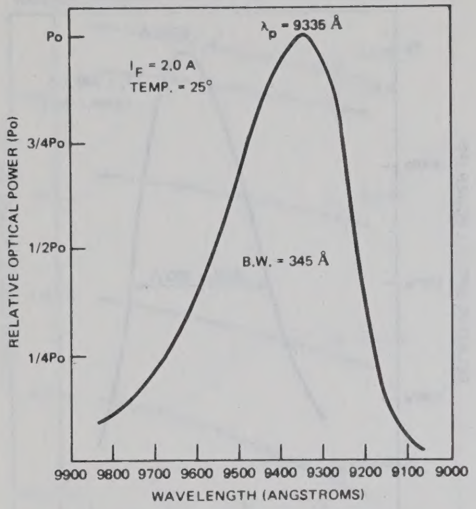


FIGURE 17. Typical Spectral Distribution For TIXL16

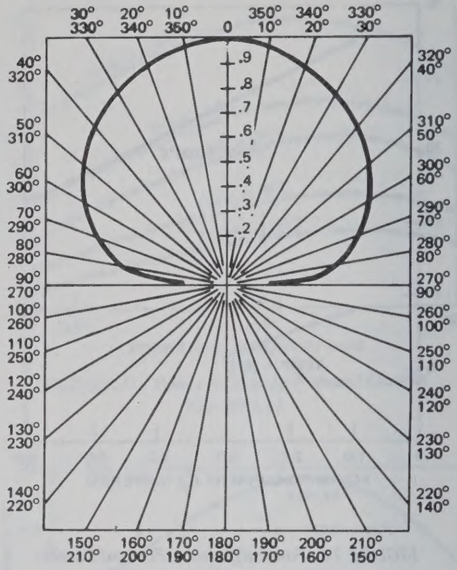


FIGURE 19. Relative Intensity-Angular Displacement For TIXL16

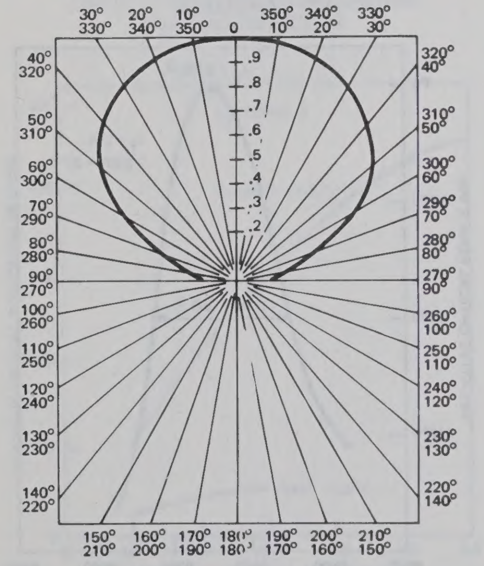


FIGURE 18. Relative Intensity-Angular Displacement For TIXL12, 13, 14, and 15

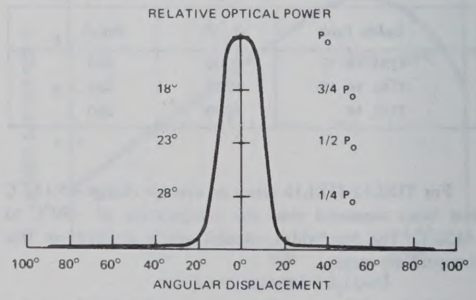
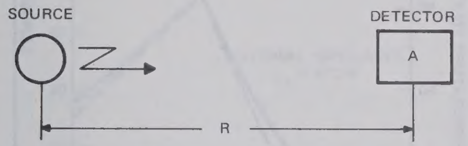


FIGURE 20. Beam Pattern For TIXL16 with Reflector

RADIANT INTENSITY

Radiant intensity is defined as radiant flux per unit solid angle in a given direction and is measured as watts/steradian.

One steradian is the solid angle subtended at the center of a sphere by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere. Radiant intensity can be measured in the following manner. Light from an emitter is beamed into an aperture of area A. The radiant flux at the aperture is measured by a detector.



The radiant intensity (J) is given by the following equation,

$$J = W/sr = \frac{P_o \text{ at detector}}{A/R^2} \qquad (6)$$

where

J = radiant intensity
A = aperture area
R = distance from source to detector

Minimum values in watts/steradian are presented in Table V for the TIXL12-TIXL16 series at their rated bias currents.

Table V

Device Type	mW/sr
TIXL 12	15.0
TIXL 13	7.0
TIXL 14	22.0
TIXL 15	11.0
TIXL 16	46.0

THERMAL IMPEDANCE

The thermal impedance can be described as the increase in temperature per watt input power (°C/W).

It is a difficult parameter to calculate accurately but can be measured with a reasonable degree of accuracy. The change in temperature from the P-N junction to heatsink can be approximated by

$$\Delta T = P_{(IN)}\,\theta_T + T_{HS} \qquad (7)$$

where

$P_{(IN)}$ = power input
θ_T = thermal impedance
T_{HS} = heatsink temperature

The method used to measure thermal impedance depends on the fact that the voltage across the P-N junction at a fixed forward current varies inversely and almost linearly with the temperature.

In practice, the diodes to be measured are first calibrated in an oven, at a constant 5 mA current, by plotting forward voltage drops at several temperatures. This gives a calibration curve for each diode.

Each diode is then placed on a constant temperature heatsink and connected to the thermal impedance test set. The test set contains circuitry for interrupting the d.c. currents for periods of 100-μs at about one per cent duty cycle. During the 100-μs period 5 mA calibrating current is applied to the diode and the forward voltage is measured.

The temperature corresponding to this voltage is read from the V_f-T calibration curve. By taking power and temperature readings at several current levels, a plot of junction temperature versus applied power may be obtained as shown in Figures 21, 22, and 23.

FREQUENCY RESPONSE

Frequency response depends on the type technology and packaging techniques used.

The frequency response curves are shown in Figure 24. These curves were obtained by forward biasing the diodes at 50 mA and modulating the d.c. bias with a 10 mA peak-to-peak sine wave signal. The output of the emitters were detected with a high speed detector. Measured values of the rise and fall times of the output of the diode, as detected by the high speed detector are 250 nanoseconds and 300 nanoseconds respectively.

The frequency response of the TIXL12-TIXL16 series is lower than the response of other Texas Instruments LEDs.

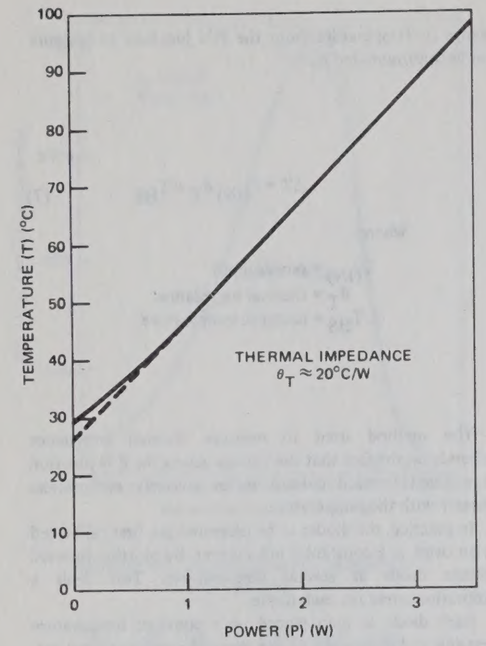


FIGURE 21. Thermal Impedance Characteristic For TIXL12

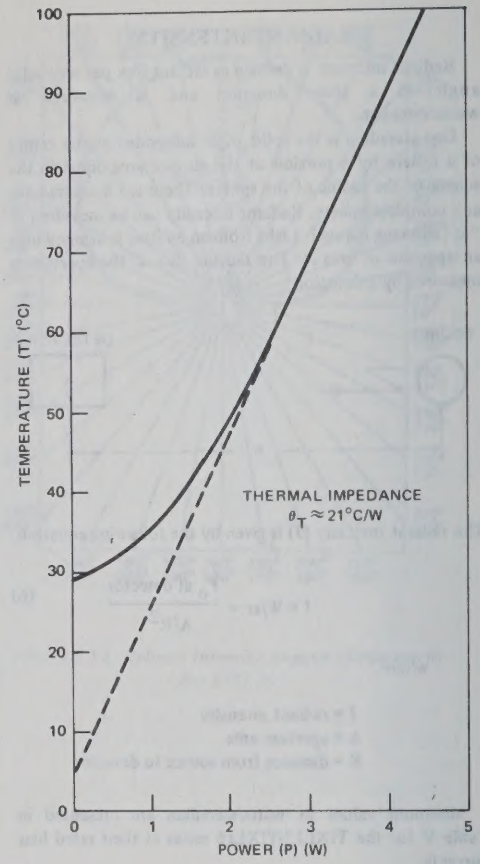


FIGURE 22. Thermal Impedance Characteristic For TIXL14 and TIXL15

PACKAGE CONFIGURATION AND DESIGN

The TIXL12-TIXL16 series of LEDs are solution-grown P-N junctions isolated by mesa formation in the shape of 36 mil or 72 mil diameter hemispheres (Figure 25).

An alloyed P-type ohmic contact is applied to the top of the mesa. A N-type contact is applied to the surrounding area.

The TIXL12-TIXL15 series are mounted on a TO-5 window package configuration which has a 6-32 stud as the anode contact and a solder lug as the cathode contact.

The TIXL-16 has the same configuration as does the TIXL14 and TIXL15 but is mounted on a heavier heat sinking stud package.

The TIXL12-TIXL15 series are hermetically sealed. The TIXL16 is not hermetically sealed. This provides a wider emission angle.

The TIXL12-TIXL15 series though normally sealed may be left unsealed at customer request.

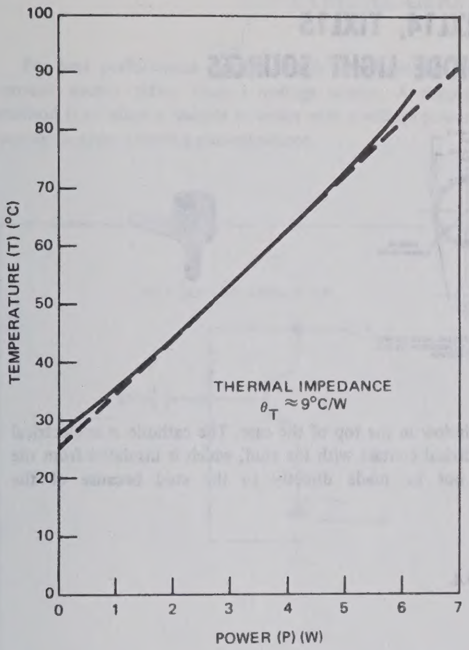


FIGURE 23. Thermal Impedance Characteristic For TIXL16

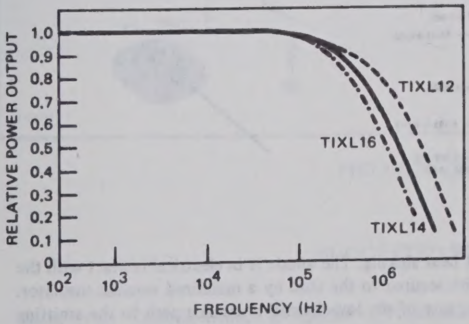


FIGURE 24. Frequency Response Characteristic For TIXL12, TIXL14, TIXL16

The TIXL12 and TIXL13 devices are 36 mil diameter hemispheres with rated optical powers of 40 mW and 20 mW at 300 mA forward bias current.

The TIXL14-TIXL15 devices are 72 mil diameter hemispheres with rated optical powers of 60 mW and 30 mW at 1 ampere forward bias current.

The TIXL16 devices are 72 mil diameter hemispheres with rated optical powers at 200 mW at 2 amperes forward bias current.

The TIXL12,13,14,15 are capable of passing environmental tests in accordance with the following Mil-Std procedures:

Thermal shock:
Mil-Std-750A, method 1056.1, condition A.

Acceleration:
Mil-Std-750A, method 2006 at a level of 15,000 G's, Y_1 & Y_2 axis.

Hermetic Seal:
Mil-Std-202, method 112, condition C, except the leakage rate shall not exceed 50 X 10^{-8} ATM CC/sec.

Solderability:
Mil-Std-750A, method 2026 as appropriate with solder lug.

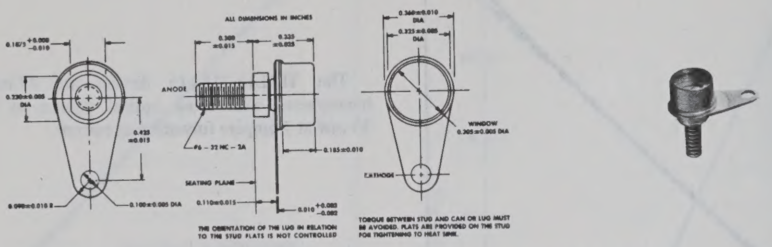
Vibration-Variable Frequency:
Mil-Std-750A, method 2056 30 G's.

Mechanical Shock:
Mil-Std-202, method 213 sawtooth pulse at 100G's.

Moisture Resistance (non-operating):
Mil-Std-750A, method 1021, except that lead fatigue test shall be omitted.

The TIXL16 is capable of passing Mil-Std environmental testing where tests are compatible with devices that are not hermetically sealed.

TIXL12, TIXL13, TIXL14, TIXL15
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCES


ALL DIMENSIONS IN INCHES
0.1875 +0.000 −0.010
0.230±0.005 DIA
0.425 ±0.015
0.090±0.010 R
0.100±0.005 DIA
ANODE
0.300 ±0.015
0.335 ±0.025
#6 – 32 NC – 2A
0.185±0.010
SEATING PLANE
0.110±0.015
0.010 +0.003 −0.002
0.360±0.010 DIA
0.325±0.005 DIA
WINDOW 0.305±0.005 DIA
CATHODE

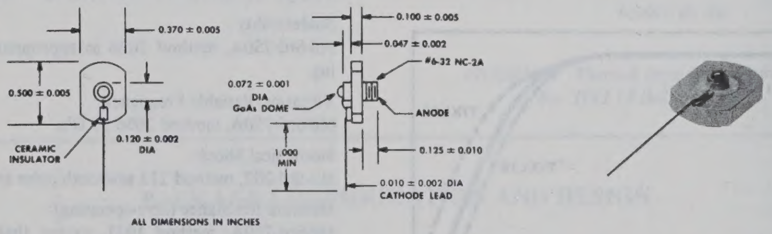
THE ORIENTATION OF THE LUG IN RELATION TO THE STUD FLATS IS NOT CONTROLLED

TORQUE BETWEEN STUD AND CAN OR LUG MUST BE AVOIDED. FLATS ARE PROVIDED ON THE STUD FOR TIGHTENING TO HEAT SINK.

The devices are in hermetically sealed packages with a flat glass window in the top of the case. The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between the stud and emitting element.

FIGURE 25A.

TYPE TIXL16
P-N GALLIUM ARSENIDE DIODE LIGHT SOURCE


0.370 ± 0.005
0.500 ± 0.005
CERAMIC INSULATOR
0.120 ± 0.002 DIA
0.072 ± 0.001 DIA GaAs DOME
0.100 ± 0.005
0.047 ± 0.002
#6-32 NC-2A
ANODE
1.000 MIN
0.125 ± 0.010
0.010 ± 0.002 DIA CATHODE LEAD
ALL DIMENSIONS IN INCHES

The diode is mounted on a copper stud header to provide efficient heat sinking. The anode is in electrical contact with the copper stud. The cathode lead is a varnished 0.01-inch copper wire secured to the stud by a metalized ceramic insulator. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path to the emitting element.

FIGURE 25B.

TYPICAL GaAs EMITTER CIRCUITS

For best performance emitters should be biased from a current source rather than a voltage source. A simple method is to place a resistor in series with a voltage power supply to approximate a current source.

Proper heat sinking is also required to insure that excessive heating does not occur and cause power output of the diodes to decrease.

Typical circuits using light emitters are shown in Figure 26. These circuits can serve as building blocks for more sophisticated and optimum circuits.

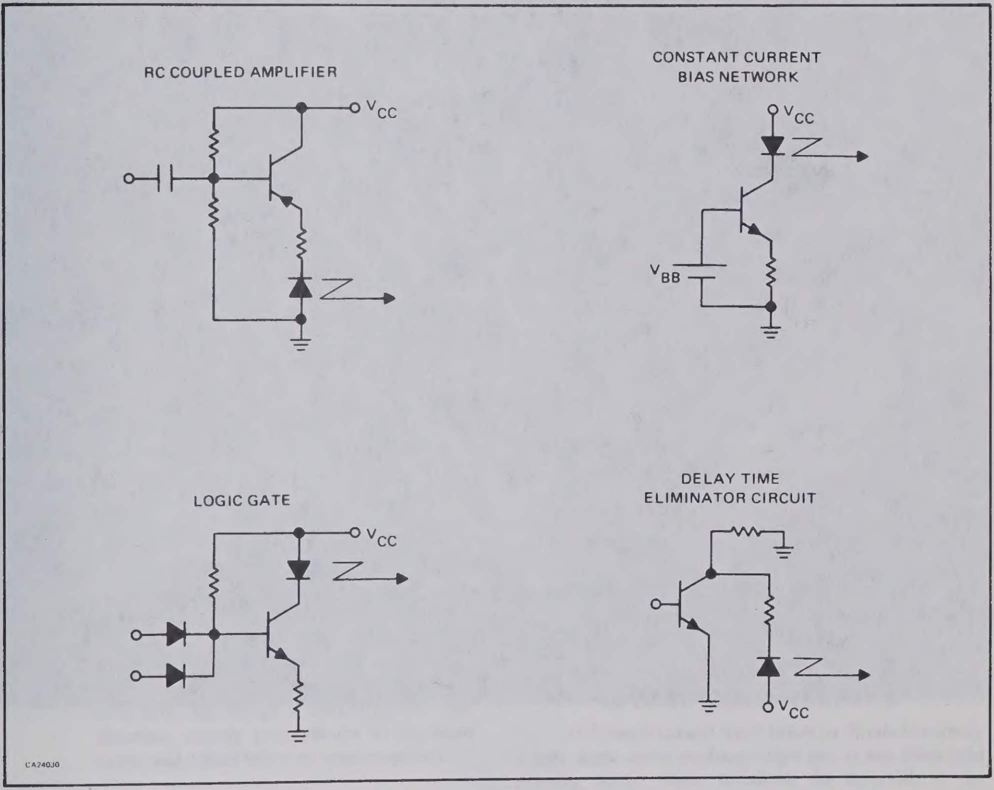

RC COUPLED AMPLIFIER
V_{CC}
CONSTANT CURRENT BIAS NETWORK
V_{CC}
V_{BB}
LOGIC GATE
V_{CC}
DELAY TIME ELIMINATOR CIRCUIT
V_{CC}
CA24030

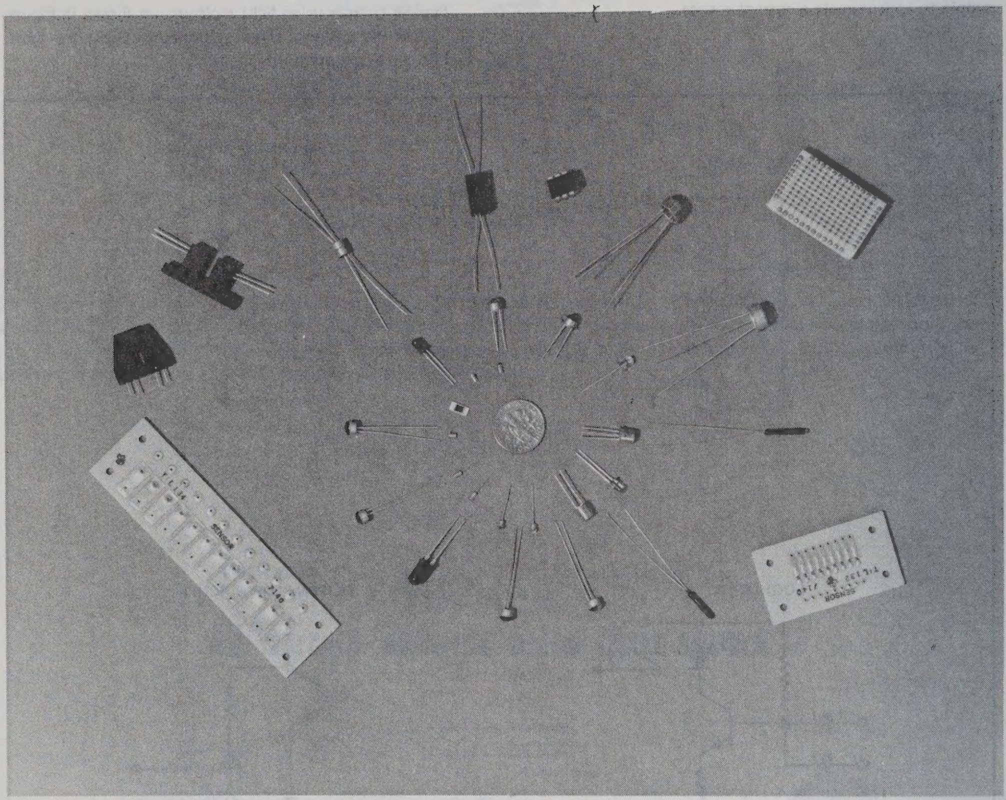
FIGURE 26. Typical Emitter Circuits

SUGGESTED FURTHER READING

Biard et al, "Optoelectronics as Applied to Functional Electronic Blocks", *Proceedings of the IEEE*, Vol. 52, No. 12, December 1964, Ppp. 1529-1536.

Millman and Halkias, "Electronic Devices and Circuits", McGraw-Hill, pp. 132-133.

Shortley and Williams, "Elements of Physics", Prentice-Hall, pp. 437-439.



INJECTION LASER DIODE FUNDAMENTALS

Ron Carroll

Injection laser diodes provide greater quantities of higher intensity light from smaller areas than conventional tungsten or light-emitting diode sources. Consequently, these semiconductor devices find a wide variety of applications in optical ranging, communications, tracking, intrusion detection, optical switching, and illumination.

This report is intended as a guide to assist in effective operation of injection laser diodes.* Basic comprehension of the topics included should provide adquate background for successful system design. Included are discussions concerning the definition and basic description, optical and electrical characteristics, and basic circuit application of injection laser diodes, specifically, Texas Instruments types TIXL28, TIXL29 and TIXL30.

DEFINITION AND BASIC DESCRIPTION

An injection laser diode is a light-emitting diode with a very planar (flat) p-n junction built between two parallel reflecting planes which define the optical cavity. As in every other type of laser – for example, gas lasers – the optical feedback mechanism leads to the generation of stimulated emission when the laser is pumped above its threshold level. The emitted energy is then coherent, which means

1. The energy is confined to a narrow frequency band, in the ideal case, monochromatic.
2. A phase relationship exists between all points of the emitted wavefront.
3. For the Fabry-Perot type cavities considered here, the energy is released in only one direction, namely perpendicular to the front cavity wall, which has to be semitransparent.

Due to the low Q (effective gain) of the optical cavity and to nonuniformities of the materials in injection laser diodes, the coherence is comparatively poor. The devices tend to "lase" in filaments which act as a number of parallel, optically independent lasers. The laser diodes described in this report are mainly used as highly efficient, narrow-bandwidth energy sources with short time constants instead of sources for coherent light. Although continous wave operation of these devices is possible at low temperatures, – for example, 50°K – discussion is restricted to pulsed operation.

Similar to other light-emitting diodes, the light is generated by a process of recombination of electrons and holes; and the wavelength of the light is determined by the bandgap and the doping of the semiconductor close to the p-n junction.

The p-n junction of a conventional gallium arsenide (GaAs) laser diode, as shown in Figure 1, is formed by a diffusion process.

A more recent development is the heterostructure laser diode, which consists of a multilayer structure as shown in Figure 2. The top p^+ layer consists of a semiconductor of slightly wider bandgap grown by an epitaxial process. If the p-n junction is properly spaced with respect to the top wide-bandgap layer, this top layer of GaAlAs does not absorb laser light and has a confining effect on the laser light beam in the GaAs crystal and on the injected electrons. This effect results in a reduction of the threshold current of the laser diode, particularly at room temperature. The heterostructure laser diode does not, however, out-perform conventional laser diodes in all respects. Due to a different fabrication process, heterostructure laser diodes have a higher series resistance, which reduces the power conversion efficiency.

OPTICAL CHARACTERISTICS

At forward current levels below its threshold current, a laser diode emits incoherent light just as any other light emitting diode. Above threshold, the linewidth of the emitted light narrows, and the light is concentrated in a beam angle of approximately 20°.

Threshold Current and Threshold Current Multiplication Factor, F

The threshold current I_{th} is defined by extrapolating the power-output-versus-driving-current curve to zero output as in Figure 3. For diffused laser diodes operated at absolute temperature T from 77 to 300°K, the threshold

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* For a more complete description of injection lasers and the physics involved, study of the following paper is recommended: M. H. Pilkuhn, "The Injection Laser," *Physica Status Solidi*, Vol. 25, 9 (1968).

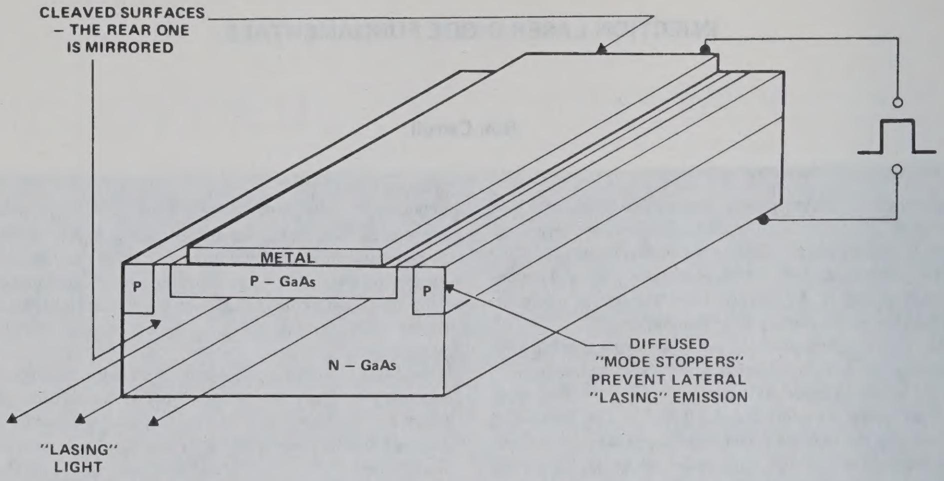
CLEAVED SURFACES – THE REAR ONE IS MIRRORED
METAL
P – GaAs
P
P
N – GaAs
DIFFUSED "MODE STOPPERS" PREVENT LATERAL "LASING" EMISSION
"LASING" LIGHT

FIGURE 1. *Configuration of a Diffused Injection Laser Diode*

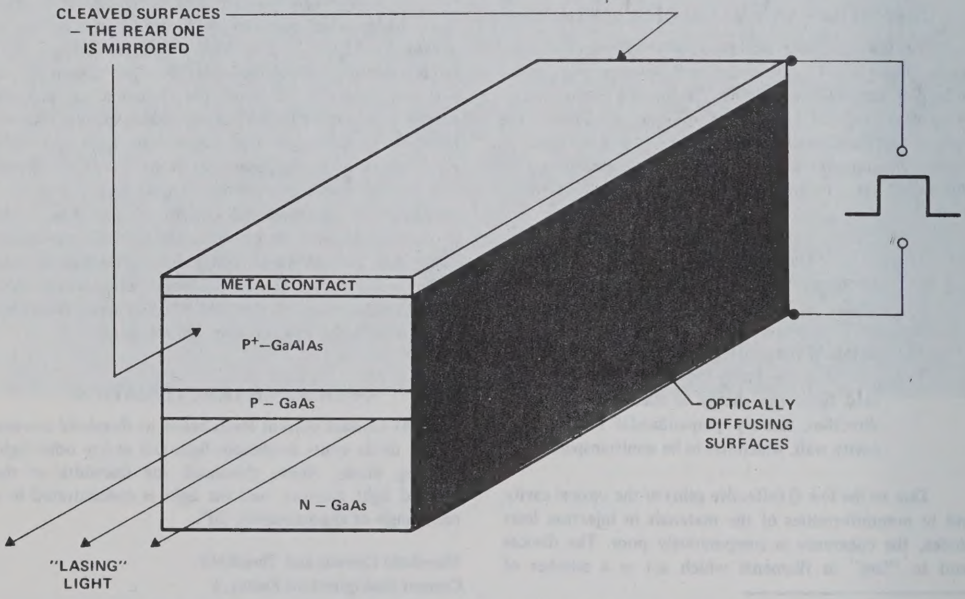
CLEAVED SURFACES – THE REAR ONE IS MIRRORED
METAL CONTACT
P^+–GaAlAs
P – GaAs
N – GaAs
OPTICALLY DIFFUSING SURFACES
"LASING" LIGHT

FIGURE 2. *Configuration of a Heterostructure Injection Laser Diode*

current varies approximately with T^3; heterostructure laser diodes are less predictable, showing a $T^{2.5}$ to T^3 dependence in this temperature range.

If injection laser diodes are operated at power levels which are too high, degradation occurs. If the optical output level exceeds about 1.5 watts per 1 mil width of the emitting junction, irreversible catastrophic degradation can occur in a few pulses.

For safe operation, a "threshold current multiplication factor" F should be considered. For a given temperature, F is the ratio of maximum safe driving current to threshold current and determines the upper limit of operation, F I_{th}. For a diffused laser at 300°K, F is about 3, for a heterostructure laser diode at 300°K, F is about 4 to 5; for

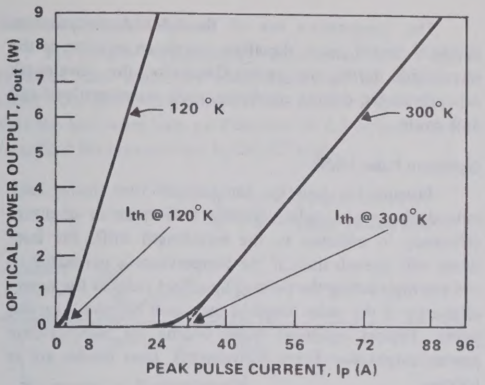

FIGURE 3. Threshold Current of Injection Laser Diode

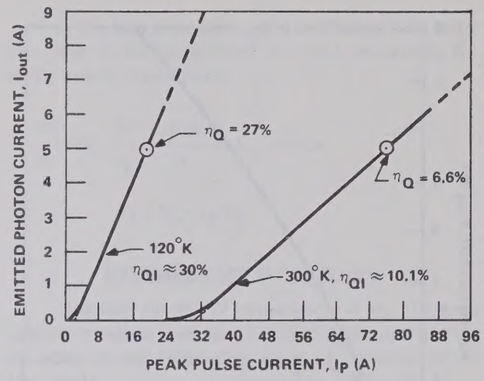

FIGURE 4. Incremental Quantum Efficiency of Injection Laser Diode

both types of laser diodes below 150°K, F is about 10 to 12. A diffused laser (F ~ 3, and 300°K) with a threshold current $I_{th} = 10$ A can therefore be safely operated for several hundred hours at 30 A driving current.

External Quantum Efficiency

The quantum efficiency η_Q of a laser diode is the ratio of the number of photons externally emitted from the junction cavity to the number of injected electrons per unit time. The devices considered in this report have one end mirrored, as shown in Figures 1 and 2, and all light for the following data is emitted from one end of the diode. Expressing current I_{in} and I_{out} in units of electrons per unit time,

$$\eta_Q = \frac{I_{out}}{I_{in}} = \frac{P_{out}/h\nu}{I_{in}}\text{; where } \nu = \frac{c}{\lambda}$$

The slope of the linear portion of a plot of I_{out} versus I_{in} as seen in Figure 4, defines the incremental quantum efficiency η_{QI} (Ip is assumed equal to I_{in}):

$$\eta_{QI} = \frac{\Delta I_{out}}{\Delta I_{in}}$$

Power Efficiency

The power efficiency of a laser diode is the ratio of optical power output to input power:

$$\eta_P = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{I_{in}\ V_{in}}$$

Both power and quantum efficiency are strongly temperature dependent and affected by the quality of the p-n junction and optical cavity, as well as series resistance R_S. The plots in Figures 5 and 6 show the power efficiency of a laser diode at two different temperatures and illustrate the effect temperature has on power efficiency. Some typical data for diffused devices with one end mirrored are cited in Table 1.

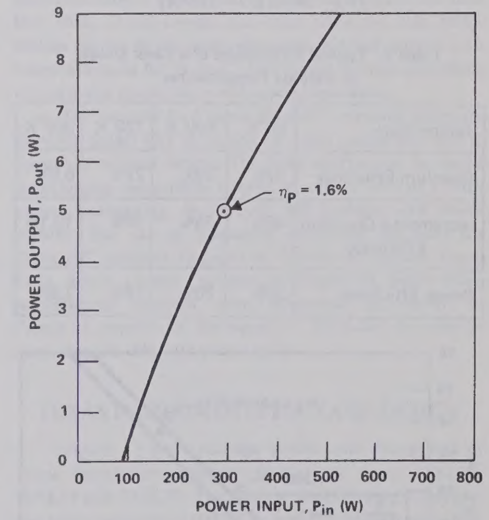

FIGURE 5. Power Efficiency of a Laser Diode [$R_S = 50$ mΩ; T = 300°K]

Wavelength Behavior

Due to the temperature dependence of the semiconductor properties, the peak emission wavelength of a laser diode shifts approximately 2.2 Å per degree K. As seen in Figure 7, a GaAs laser diode has a wavelength of approximately 9000 Å at 300°K, and approximately 8600 Å at 120°K.

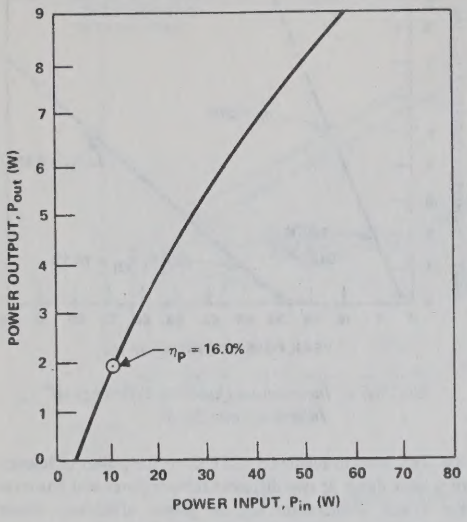

FIGURE 6. Power Efficiency of a Laser Diode [R_S = 50 mΩ; T = 120°K]

Table 1. Typical Efficiencies of a Laser Diode at Various Temperatures

Temperature	80°K	100°K	120°K	300°K
Quantum Efficiency	37%	30%	27%	6.6%
Incremental Quantum Efficiency	45%	35%	30%	10.1%
Power Efficiency	30%	20%	16%	1.6%

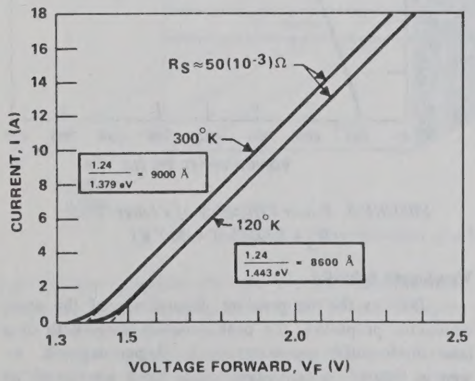

FIGURE 7. Peak Emission Wavelength Shift of GaAs Laser Diode

The temperature rise of the laser diode junction during a current pulse, therefore, causes an increase of the wavelength during the pulse. Generally, the wavelength depends on the driving condition, such as current level and duty cycle.

Optimum Pulse Width

Because the junction temperature rises during each individual current pulse, causing a decrease in quantum efficiency in addition to the wavelength shift, the laser diode will quench itself if the temperature is permitted to rise too high during the pulse. This effect reduces the power efficiency if the pulse length is increased beyond a certain point. Typical optimum pulse widths for high average power output for Texas Instruments laser diodes are as follows:

for diffused laser diodes at 300°K,	t = 300 ns,
for heterostructure laser diodes at 300°K,	t = 800 ns,
for either kind below 150°K,	t = 2000 ns.

In order to achieve an output pulse of 2 μs and to be able to operate the laser diode at high duty cycles (for example, 3%) the junction must be placed as close to the heat sink as possible. This provision at the same time reduces the electrical series resistance. The thermal impedance for cooled TI laser diodes is approximately 15°C/W or less.

Output Delay

At temperatures above 150°K, injection laser diodes show a delay of the light output after application of the current pulse. Typical delays, as depicted in Figure 8, vary from 40 ns to 140 ns. At lower drive current, the delay is longer. The delay is affected by the device fabrication process and the crystal material used, but does not fluctuate for a given device. Heterostructure laser diodes generally have slightly longer delays than diffused laser diodes. This delay reduces the output power per current pulse and must be considered for efficiency computations.

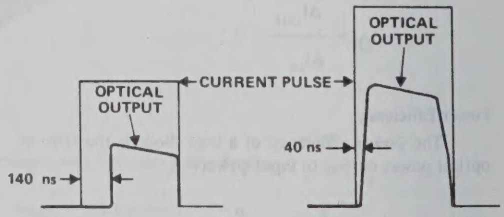

FIGURE 8. Typical Delay of the Light Output After Application of the Current Pulse

Simple Collimation Optics

For simple collimation of rays emitted from a single injection laser diode the beam angle must be considered about 20 degrees total width. It can be seen from Figure 9 that the lens must have an f number of 2.8 or less in order to collect the rays emitted in the 20° angle.

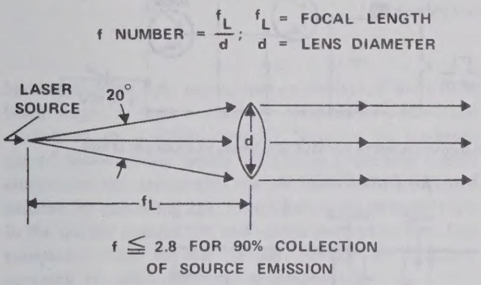
f NUMBER = $\frac{f_L}{d}$; f_L = FOCAL LENGTH
d = LENS DIAMETER
LASER SOURCE
20°
d
f_L
f ≦ 2.8 FOR 90% COLLECTION OF SOURCE EMISSION

FIGURE 9. Beam Angle and Lens for Simple Collimation of Rays Emitted From a Single Injection Laser Diode

ELECTRICAL CHARACTERISTICS

The electrical characteristics of a laser diode are that of a semiconductor diode built into highly-doped material. The reverse breakdown voltage is low (typically 2 V) and the laser diode must be protected from higher reverse voltage pulses to prevent degradation. In the forward direction, the laser diode behaves like a diode obeying the usual exponential law:

$$V_F = \frac{nkT}{q} \log_e \frac{I_F}{I_S} + I_F R_S$$

where

V_F = diode forward voltage drop
I_F = diode forward current
q = electron charge
k = Boltzmann constant
T = temperature in degrees Kelvin
I_S = diode saturation current
R_S = diode series resistance
n = constant, which for GaAs can vary from 1.2 to 2.0
V_b = built-in junction voltage
V_R = reverse breakdown junction voltage
c = speed of light
λ = peak emission wavelength of laser (in μm) at temperature T
h = Planck's constant

At the high currents required for "lasing," the $I_F R_S$ term must be considered. And at a given temperature for similar heavily doped diodes,

$$\frac{nkt}{q} \log_e \frac{I_F}{I_S} \approx \frac{1.24}{\lambda} \approx V_b \text{ . Hence}$$

$$V_f = V_b + I_F R_S \; .$$

RECOMMENDED CIRCUITS

Referring to the T^3 dependence of the threshold current, it will be seen that electrical requirements differ according to the temperature range of operation of the laser diode.

In cooled-device operation, the reduced current requirements and larger chip size do not demand pulses with extremely fast rise and fall times. The optical output pulses duplicate the input current pulses – even with rise and fall times of as long as 300 ns.

For device operation around 300°K, however, the requirement of higher current density and consequently smaller chip size imposes additional pulse restrictions. This increased current pulse must be produced in much less time (less than 50 ns). Longer rise times cause the chip temperature to rise to the point where the injected current is no longer adequate for "lasing". This means thermal quenching occurs much sooner than with cooled operation.

The circuits in Figures 10 and 11 provide adequate rise-time pulses (30 to 50 ns) for both cooled and 300°K operation of laser diodes. The pulse widths may be varied by changing capacitance C (not to exceed 0.02 μF). With proper heatsinking, the circuits will perform well above 20 kHz. The use of transistors eliminates the need for "turn-off" circuitry required in SCR-driven circuits. From basic driver circuits, as seen in Figure 10, some more sophisticated versions were developed, as shown in Figure 11, capable of driving up to 20 diodes in series at more than 30 kHz with pulses up to 1.5 μs.

TEXAS INSTRUMENTS PACKAGE DESIGN

Figure 12 gives package details and dimensions of Texas Instruments injection laser diode types TIXL28, TIXL29 and TIXL30. The primary material used is oxygen-free high-conductivity (OFHC) copper. It permits operation from 77 to 450°K. Unless otherwise specified, the contact tab is the cathode and the threaded part, is the anode.

EYE PROTECTION

Some disparity exists among authorities concerning the energy density of collimated light incident on the cornea which will produce eye damage*. Retinal lesions can

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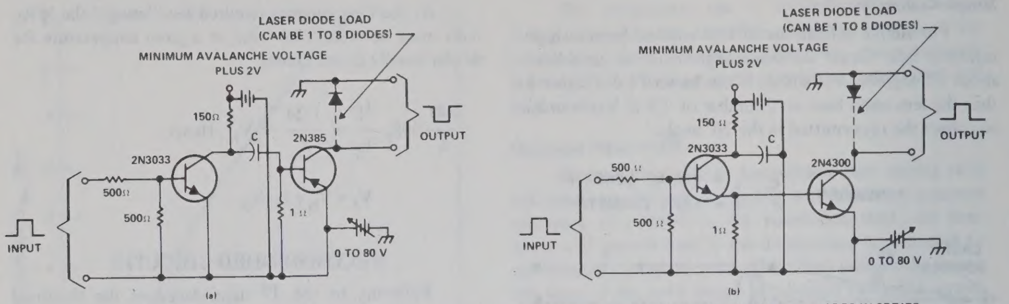
* "Human Biological Interaction With Laser Light", T. O. Huston, U. S. Gov't Report AD 660361, 2 August 1967.


LASER DIODE LOAD (CAN BE 1 TO 8 DIODES)
MINIMUM AVALANCHE VOLTAGE PLUS 2V
150Ω
C
2N385
OUTPUT
2N3033
500Ω
500Ω
1Ω
INPUT
0 TO 80 V
(a)
LASER DIODE LOAD (CAN BE 1 TO 8 DIODES)
MINIMUM AVALANCHE VOLTAGE PLUS 2V
150Ω
C
2N3033
2N4300
OUTPUT
500Ω
500Ω
1Ω
INPUT
0 TO 80 V
(b)

NOTE: (a) AND (b) PRODUCE FAST-RISE PULSES SHORTER THAN 500 NANOSECONDS IN WIDTH CAPABLE OF DRIVING 1-8 DIODES IN SERIES.

FIGURE 10. Basic Driver Circuit for Laser Diode

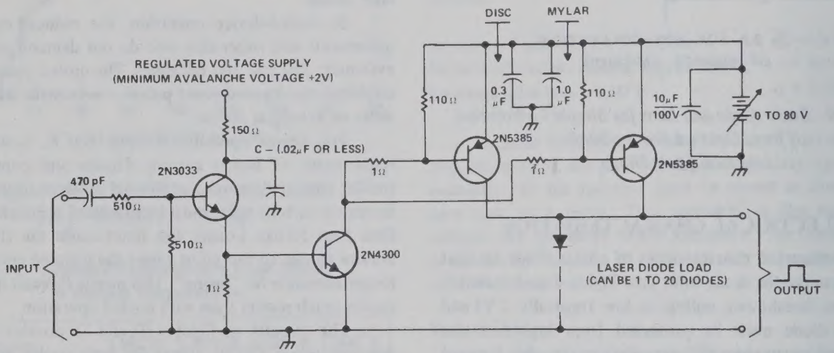

DISC
MYLAR
REGULATED VOLTAGE SUPPLY (MINIMUM AVALANCHE VOLTAGE +2V)
110Ω
0.3 μF
1.0 μF
110Ω
10μF 100V
0 TO 80 V
150Ω
C – (.02μF OR LESS)
2N5385
1Ω
1Ω
2N5385
2N3033
470 pF
510Ω
510Ω
2N4300
INPUT
1Ω
LASER DIODE LOAD (CAN BE 1 TO 20 DIODES)
OUTPUT

FIGURE 11. Driver Circuit Capable of Driving Up to 20 Laser Diodes in Series

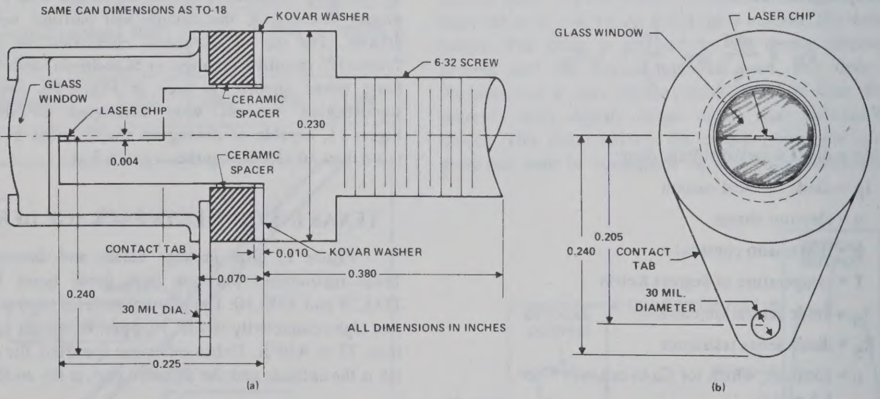

SAME CAN DIMENSIONS AS TO-18
KOVAR WASHER
6-32 SCREW
GLASS WINDOW
LASER CHIP
CERAMIC SPACER
0.230
0.004
CERAMIC SPACER
CONTACT TAB
0.010
KOVAR WASHER
0.070
0.380
0.240
30 MIL DIA.
ALL DIMENSIONS IN INCHES
0.225
(a)
LASER CHIP
GLASS WINDOW
0.205
0.240
CONTACT TAB
30 MIL. DIAMETER
(b)

FIGURE 12. Package Design of Texas Instruments Injection Laser Diode

be produced under proper conditions from $7(10^{-9})$ J/cm^2 to 8.7 (10^{-8}) J/cm^2. It is reasonably easy to generate these energy densities in laboratory use of both cooled and room-temperature lasers, during such operations as microscopic study of the "lasing" junction, direct viewing through a metascope during alignment of system optics, and particularly the viewing of a well-collimated beam 2 mm or less in width. **PROPER WAVELENGTH LASER GOGGLES SHOULD BE WORN WHEN THE POSSIBILITY OF EXPOSURE TO THESE LEVELS EXISTS.**

MEASURING LIGHT-EMITTING DIODE OUTPUT

Ronald D. Grotti and Larry D. Major
Optoelectronics Department

Making accurate light measurements involves, if not a little black magic, at least a relatively complicated commercial instrument and a skilled operator. However, the increased use of light-emitting diodes (LEDs) as a precision system component has necessitated the development of equipment suitable for measuring light from LEDs in the designer's lab, in the quality control lab, and on the production line. This equipment must be easy to use, provide the necessary accuracy, be calibratable, and be inexpensive.

To develop such equipment requires the selection of a suitable photodetector and the development of the proper calibration and operation procedures. This report describes a method that has been used in the Texas Instruments Optoelectronic Device Department for measuring the output of its light-emitting diode products. The apparatus consists simply of a photovoltaic light sensor connected directly to an ammeter, with a special mechanical fixture to prevent escape of light.

SELECTION OF LIGHT SENSOR

Detectors that might be considered for measuring LED output include thermopiles, photocells, photodiodes, photomultipliers and photovoltaic cells. To show why the photovoltaic cell was chosen for this application, a review of pertinent detector characteristics is in order.

Thermopiles can be excellent primary detecting devices, but are generally unsuitable for most laboratory and quality control types of service. Not only are they difficult to apply properly, but they are costly, lose their calibration when mishandled, and have an inadequate frequency response.

Photodiodes have good frequency capabilities, are reasonably priced, and are being used in pulse and high-frequency applications. However, most LEDs are tested under low-frequency conditions, and therefore frequency response is not a critical sensor parameter. Because the photodiode must be electronically biased, a well-regulated bias supply is required to insure consistent results.

Good sensitivity and frequency response plus a large detection area are some photomultiplier features. But multi-element phototubes are expensive, require high-voltage supplies, and since output is a function of supply voltage, stability problems can arise. Also, if improperly applied, photomultipliers can saturate, causing errors and possibly permanent tube damage.

Photovoltaic cells—particularly the solar-cell variety—have a large active area, good long-term stability, and good spectral matching, are easy to use, and are inexpensive. The frequency response from dc to 100 kHz, although less than that of the photomultiplier and photodiode, is satisfactory for this application. These factors, combined with the fact that power or bias supplies are not required, makes the solar cell appear to have the best combination of qualities for this application.

Using the photovoltaic cell to precisely measure the LED output and determine its quantum efficiency requires detailed knowledge of the cell, the emitter, and how they are optically coupled. Such knowledge depends not only the mathematical characterization of the two devices, but on an accurate calibration of the photovoltaic cell. Once these steps have been accomplished, the LED's power output and its quantum efficiency can be calculated using only two measured values – the emitter's input current and the cell's output current.

THE PHOTOVOLTAIC CELL

Before describing how the photovoltaic cell is calibrated, a few comments on the basic characteristics of this semiconductor device are in order. It is not necessary for our purposes to discuss the theory of operation in detail. Suffice it to say that electron-hole pairs are generated within the device as a function of impinging photons. Only those photons that have a quantum energy larger than the band gap between the valence band and the conduction band generate electron-hole pairs. The lower-energy photons simply transmit through the cell and do not cause an output. The ratio of electrons generated to the total number of incident photons is the cell's quantum efficiency, and is defined as

$$\eta_{SC} = \frac{\text{electrons generated/sec}}{\text{incident photons/sec}}$$

It is necessary to note that the cell's quantum efficiency is a function of the wavelength (Figure 1). This fact is particularly important because the sensor specifications are often based on the device's sensitivity to a particular wavelength. This quantum efficiency curve can be shaped through various means including the deposition of anti-reflection coatings on the photovoltaic cell's surface.

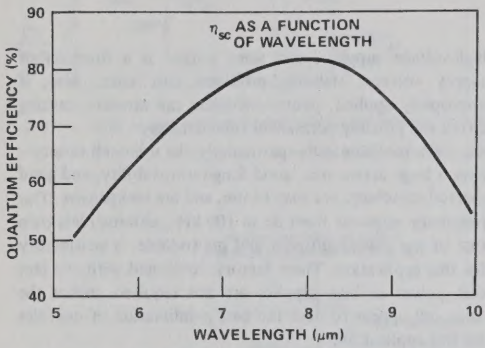


FIGURE 1. Photodetector Quantum Efficiency Varies as a Function of Wavelength, Thus Making Calibration at a Number of Wavelengths Necessary for General Use

CELL CALIBRATION

Before using the photovoltaic cell to measure the LED power output, the cell must be calibrated. This calibration is a two-step process, with the first step being the accurate determination of the cell's relative response. This determination is made using a grating monochromator, a tungsten light source, and a thermocouple detector that has a flat response in the spectral region of 500 nm to 1000 nm. Two curves are obtained, one using the thermocouple detector to measure the tungsten source's output and the other using the photovoltaic detector to measure the same output.

By dividing the photovoltaic cell response by the thermocouple response, the relative response of the cell is obtained. The relative response curve allows the measurement of light sources with different spectral characteristics to be accurately compared. However, to determine the actual power generated by a particular source using this cell requires another calibration step in which the photovoltaic cell output is determined when illuminated by a light source with a known power output. To accomplish this goal, the output of three monochromatic sources (gallium arsenide LED, helium-neon laser, and argon laser) are measured by the cell being calibrated and by an Eppley thermopile. The quantum efficiency of the cell at the wavelength of each emitter is then found by using the optical power equation:

$$\eta_{sc} = \left(\frac{I_L}{\text{optical power}}\right)\left(\frac{\text{energy}}{\text{photon}}\right)$$

where I_L is the short-circuit current from the photovoltaic cell under test and optical power is the measurement made by the thermopile.

The three quantum efficiencies are then plotted, and a curve is generated that allows the cell to be used to measure accurately any impinging light of known spectral characteristics.

MEASUREMENT PROCEDURE

To employ this calibrated detector in an LED testing system, it is necessary to develop the relationships that can describe the LED's quantum efficiency.

The LED output is directly proportional to the emitted photon energy and quantity per unit of time. The relation between energy E and wavelength λ is defined as

$$\lambda = \frac{1{,}24}{E} \quad \text{or } E = \frac{1.24}{\lambda} \qquad \text{(units are } \mu\text{m and eV)}$$

Energy, and therefore wavelength, of any given photon emitted from an LED source fall within a distribution curve such as that shown in Figure 2 for a GaAs LED. To be absolutely accurate in calculating the optical power output of a solid-state source requires a time-consuming graphical integration using Figure 1 and Figure 2. Fortunately, all photons emitted by a monochromatic source have the same energy. Since it is a valid assumption to consider the LED to be monochromatic, the LED's optical power can be described to a first approximation without any noticeable error.

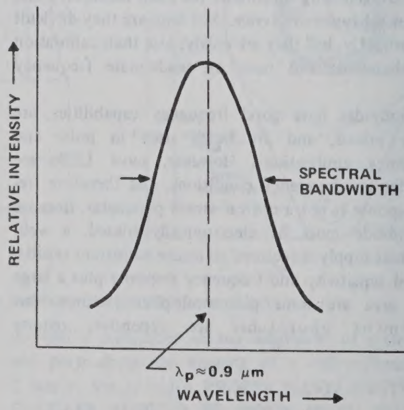


FIGURE 2. Spectral Characteristics of GaAs Diode Indicate that the Device is Nearly Monochromatic

For simplicity of calculation, let us assume that all photons generated by the LED are collected by the photovoltaic cell. Therefore, considering the ammeter as a load consisting of a calibrated resistor and microvoltmeter, (Figure 3), the current I_L (neglecting the internal resistance R_{shunt} of the photocell) is proportional to the number of photons striking the surface:

$$I_L = \left(\frac{\text{electrons}}{\text{sec}}\right) (1.062 \times 10^{-19})$$

and

$$I_L = \eta_{sc} \left(\frac{\text{photons}}{\text{sec}}\right) (1.602 \times 10^{-19})$$

therefore,

$$\text{photons/sec} = \frac{I_L}{\eta_{sc} (1.602 \times 10^{-19})}$$

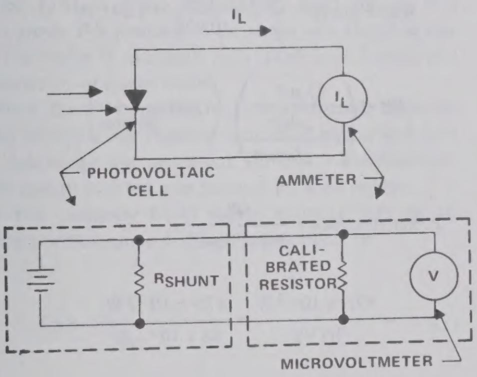


FIGURE 3. Equivalent Circuit of a Photovoltaic Cell (Silicon Solar Cell) Connected to the Ammeter Used to Measure Short Circuit Current

Knowing I_L, we can now calculate the emitter quantum efficiency η_{em} and optical power OP :

$$\eta_{em} = \frac{I_L}{\eta_{sc} I_D} \quad \text{where } I_D \text{ is LED current}$$

$$OP = \left(\frac{I_L}{\eta_{sc}}\right) \left(\frac{\text{energy}}{\text{photon}}\right)$$

Using these equations, we can indeed determine both the quantum efficiency and the optical power generated by the LED under conditions where all the power emitted is collected by the photovoltaic cells. To insure the photovoltaic cell receives all emitted photons, it is necessary to build special testing jigs using detectors either singly or in arrays. (See Figures 4 and 5). In either case, the test procedures are the same. However, if such jigs are not possible, then the percentage of light emitted that actually reaches the detector must be included in the calculation. This fraction can be determined by dividing the total power emitted by the steradian relationship between the detector and the emitter, the total number of steradians being equal to the aperture area of the detector divided by the square of the distance between the emitter and the detector surface.

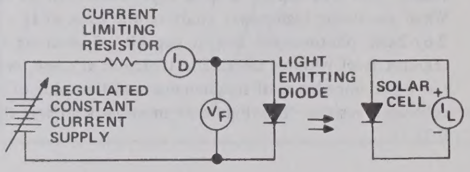


FIGURE 4. Test Setup for Calibrating LEDs

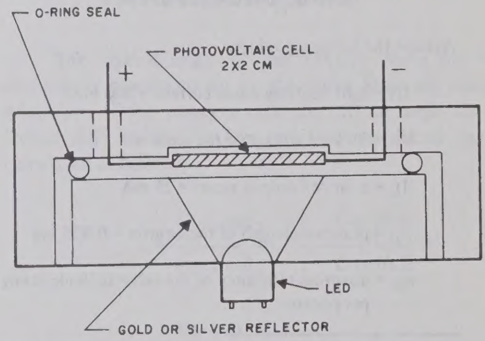


FIGURE 5. Test Jig for Capturing the Total LED Output with a Single Photovoltaic Cell

TESTING PRECAUTIONS

Generally, gallium arsenide and gallium arsenide phosphide (GaAsP) infrared emitters provide an output signal I_L large enough that an ammeter may be used to measure the cell's short-circuit current directly. The measurement of GaAsP visible-light-emitting diodes and tests such as radiant intensity measurements usually produce signal levels that require a calibrated resistor and a microvoltmeter. The important point is that the input impedance of the measuring instrument must be less than 1/10 the value of R_{shunt} to prevent lowering the output of the cell. The exact value of R_{shunt} for photovoltaic cells is difficult to measure, but it is usually in the order of 10 to 30 kΩ. If the cell has been mistreated, the R_{shunt} may be as low as 1 kΩ or less. Thus, if an electronic ammeter is used in the 3×10^{-6} ampere range, as may be required for testing GaAsP visible-LEDs, the input meter impedance of 300 to 1000 Ω approaches the critical value of the typical solar cell. Thus, these low-level measurements must be made using the resistor-microvoltmeter technique.

The second problem occurs when the photovoltaic cell becomes appreciably self-biased, because of the voltage drop developed across the load. Care must be taken to limit this bias to prevent a reduced output signal. As a rule of thumb, this load-voltage drop is kept lower than 50 mV. When measuring high-power emitters, the value of I_L of a 2-by-2-cm photovoltaic cell is capable of reaching the 200-mA level without saturation; therefore at these levels, the input impedance of the ammeter and the value of the calibrated resistor (See Figure 3) must be kept less than 0.25 Ω.

SAMPLE CALCULATION OF LED POWER OUTPUT AND QUANTUM EFFICIENCY

Assume the following values:

I_D = light emitting diode current = 300 mA

V_F = forward voltage of the emitter = 1.6 volts

I_L = solar cell output signal = 25 mA

λ_p = peak wavelength of the emitter = 0.925 μm

η_{sc} = quantum efficiency of the cell = 0.70 electrons per photon

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This material appeared as an article in *Electro-Optical Systems Design*, Vol. 2 No. 7, July 1970.

Then:

η_{em} = emitter quantum efficiency

$$= \left(\frac{I_L}{\eta_{sc}}\right)\left(\frac{1}{I_D}\right) = \left(\frac{25\text{ mA}}{0.7\,\dfrac{\text{elect}}{\text{photon}}}\right)\left(\frac{1}{300\text{ mA}}\right)$$

$$= 0.119\text{ photons/electron}$$

$$\eta_{em} = 11.9\%$$

$$\text{Optical Power} = \text{OP} = \left(\frac{I_L}{\eta_{sc}}\right)\left(\frac{\text{energy}}{\text{photon}}\right)$$

$$\text{Where energy} = \frac{1.24}{\lambda_p} = \frac{1.24}{0.925} \sim 1.341\text{ eV}$$

$$\text{OP} = \left(\frac{25\text{ mA}}{0.7\,\dfrac{\text{elect}}{\text{photon}}}\right)\left(1.341\,\frac{\text{eV}}{\text{photon}}\right)$$

$$\text{Power efficiency} = \frac{\text{OP}}{\text{Input Power}}$$

$$= \frac{47.9 \times 10^{-3}\text{ W}}{I_D V_F} = \frac{47.9 \times 10^{-3}\text{ W}}{48 \times 10^{-2}\text{ W}}$$

Power efficiency = 0.0998 = 9.98%

TIXL27 GaAs SPONTANEOUS LIGHT EMITTER

The TIXL27 GaAs spontaneous light emitter is essentially a solution-grown P-N junction. The output of the device is 15 mW minimum with 20 mW being typical at the rated forward current. The device emits in the near-infrared region.

This report presents basic information necessary to utilize this high-power low-cost industrial emitter. Included in this discussion are the theory of operation, device performance including forward voltage, optical power, spectral distribution, radiance, radiant intensity, thermal impedance, pulse mode operation and optical design considerations plus typical mechanical specification and application data.

THEORY OF OPERATION

The TIXL27 GaAs spontaneous light emitter is a solution grown P-N junction in the shape of a 16 mil square wafer. The wafer is mounted on a TO-5 stud header and encapsulated in an epoxy dome.

When the P-N junction is forward biased, electrons from the N-region are injected into the P-region and light quanta (photons) are generated through recombination. The light energy emitted is in the near-infrared region.

A flat geometry GaAs source emitting into an air media has a critical angle that can be described by

$$\mathrm{Sin}\theta_c = \frac{N_1}{N_2} \qquad (1)$$

where N_1 = index of refraction of air = 1

N_2 = index of refraction of GaAs = 3.6

θ_c = critical angle = 16.2°.

Any light generated that strikes the surface of the wafer at an angle greater than the critical angle will not escape the material but will be reflected internally. This is shown in Figure 1.

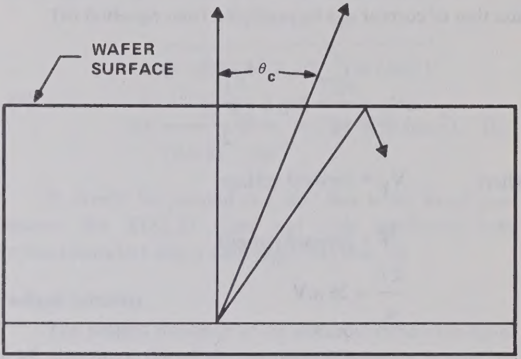


FIGURE 1. Angle of Light Determines if it Escapes or is Reflected Internally

The critical angle of the TIXL27 wafer has been changed by placing epoxy on the wafer. Since the index of refraction of the epoxy is 1.5, the critical angle changes from 16.2° to 24.6°. The improvement factor can be calculated as follows:

$$\alpha = \frac{1 - \mathrm{Cos}\theta_2}{1 - \mathrm{Cos}\theta_1} = \frac{1 - \mathrm{Cos}\ 24.6}{1 - \mathrm{Cos}\ 16.2} = \qquad (2)$$

$$\frac{1.0 - 0.91}{1.0 - 0.96} = 2.25$$

The improvement factor is valid only when the light that is emitted from the P-N junction can be transmitted through the epoxy and into the air.

The external quantum efficiency of the device can be described as the ratio of optical current output divided by forward input current.

$$N_s = \frac{I_\phi}{I_F} \qquad (3)$$

DEVICE PERFORMANCE

Forward Voltage

At a constant temperature, the voltage change as a function of current can be predicted from equation (4):

$$\Delta V_F = \frac{nKT}{q} \log e \frac{I_{F_1}}{I_{F_2}} \qquad (4)$$

where V_F = forward voltage

I_F = forward current

$\frac{KT}{q} \approx 26$ mV

n = constant

The value of n ranges from 1 to 3 for the TIXL27 with n being larger at small forward bias currents. Exact values for n may be obtained by characterizing the diode under the operating conditions to which it will be exposed.

The typical distribution of the forward voltage at the rated current of 300 mA will range from 1.3 volts to a maximum of 2.2 volts.

Optical Power

The TIXL27 generates an optical output power of 15 mW minimum. The optical output power approximates a linear function of the forward bias current when operated above a few milliamperes and at or below the maximum specified forward current. Figure 2 shows relative optical power versus forward drive current.

The optical output power can be described by Equation (5):

$$P_o = I_\phi E$$

where I_ϕ = optical output current = $\eta_s I_F$ (5)

$$E = \frac{1.24}{\lambda}$$

λ = peak wavelength in micrometers.

The optical power of the TIXL27 varies inversely with temperature. A typical curve of optical output power versus temperature is shown in Figure 3.

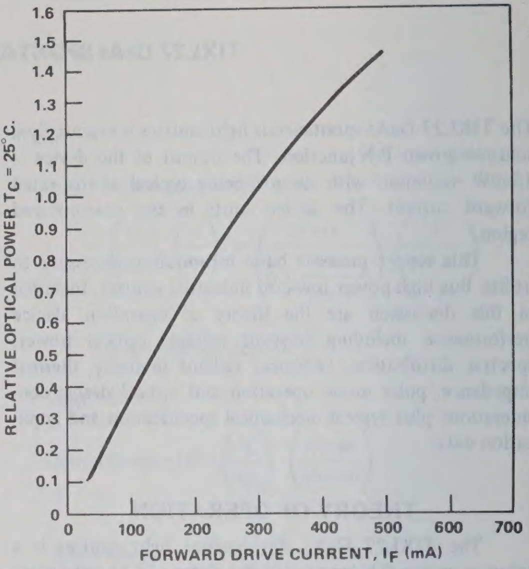


FIGURE 2. Relative Optical Power versus Forward Drive Current for TIXL 27. T = 25°C.

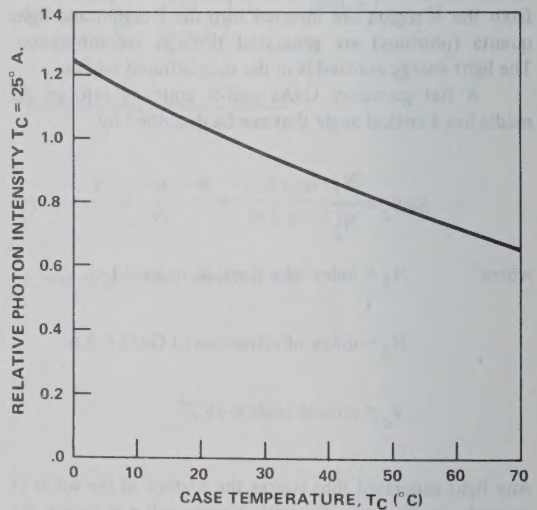


FIGURE 3. Relative Photon Intensity versus Case Temperature

Spectral Distribution

The distribution of emission wavelengths of the TIXL27 is narrow; half-power wavelengths are typically separated by 450 angstroms. The peak wavelength ranges from 9300 to 9450 angstroms when operated at rated forward current at 25°C stud temperature. The peak wavelength (λp) is a function of forward bias current and temperature. The change in wavelength of peak intensity versus case (stud) temperature is shown in Figure 4.

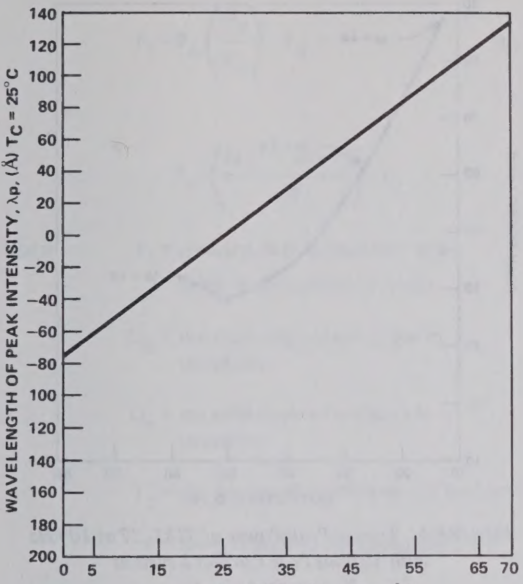


FIGURE 4. Change in Wavelength of Peak Intensity versus Case (Stud) Temperature. I_F = 300 mA.

Radiance

Radiance (N) is defined as radiant intensity emitted per unit area. In the case of the TIXL27, the radiance can be calculated by using Equations (5) – (8):

$$P_o = I_\phi E$$

where I_ϕ = optical output current = $\eta_s I_F$ (5)

$$E = \frac{1.24}{\lambda}$$

λ = peak wavelength in micrometers.

$$N = \frac{P_o}{\Omega - A} \qquad (6)$$

where P_o = total optical power

Ω = solid angle of emission in Steradians

A = Area of active region in cm^2.

For the TIXL27,

$$N = \frac{15 \text{ X } 10^{-3}\text{W}}{(2\pi)\text{Sr}(1.650 \text{ X } 10^{-6}\text{cm}^2)} = \qquad (7)$$

$$\frac{15 \text{ X } 10^{-3}\text{W}}{(6.28)\,(1.65 \text{ X } 10^{-3})\text{ Sr}\,(\text{cm}^2)}$$

$$N = \frac{15 \text{ W}}{10.4 \text{ Sr} - \text{cm}^2} = 1.44 \text{ W/Sr}\,(\text{cm}^2). \qquad (8)$$

It should be pointed out that this is the worst case because the TIXL27 does not emit uniformly into 2π Steradians but into a solid angle less than 2π.

Radiant Intensity

The radiant intensity of an isotropic radiator is equal in all directions, therefore, the radiant intensity is equal to

$$J = \frac{P}{2\pi}. \qquad (9)$$

where J = radiant intensity W/Sr

P = total optical power – W

However, most GaAs light emitters are not perfect isotropic radiators and the radiant intensity is higher on the optical axis or within a few degrees of the optical axis. Figure 5 shows a typical intensity pattern for the TIXL27.

Thermal Impedance

The thermal impedance of the TIXL27 is typically in the range of 12°C/W. The device wafer is mounted directly to the TO-5 stud which when heatsinked properly can be approximated to the first order as an infinite heatsink. It is important to note that the thermal impedance is a very difficult parameter to calculate and measured values from different groups of processed material may have a wide distribution.

Pulse Mode Operation

The TIXL27 is capable of being pulsed at relatively high peak currents. The limiting factor, as it is in most pulsed mode applications, is the interfaces and not the P-N junction–the power density gets so large in the bonding wire or the contact pad that catastrophic failures occur. For example, a 1 mil gold wire that is 0.5 inches long has a power density of approximately 4200 W/cm^3 with 300 mA flowing through it. However, by increasing the current to 1 amp, the power density increases to approximately 47,000 W/cm^3.

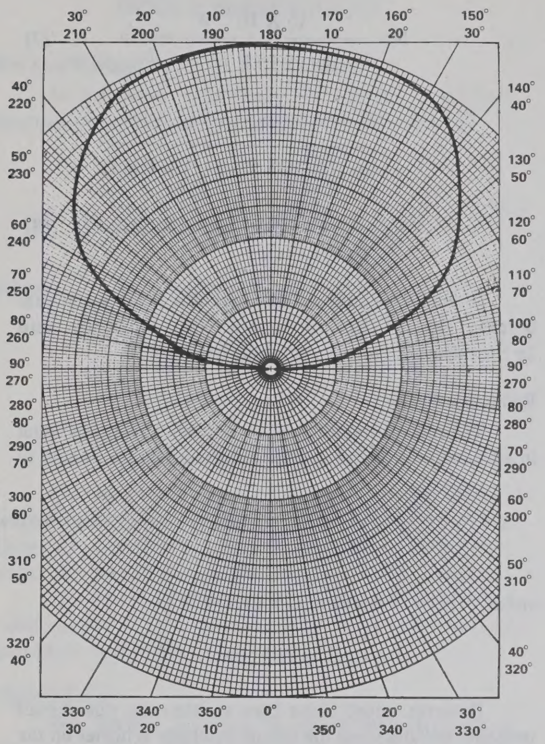


FIGURE 5. A Typical Intensity Pattern for the TIXL 27

There are tradeoffs that must be considered when operating in the pulse mode such as duty cycle, repetition rate, and peak current. The peak current can be approximated with reasonable accuracy by using

$$I_p = I_{F/D} = I_F\left(\frac{T}{t}\right) \qquad (10)$$

where I_p = peak current

I_{F_M} = Maximum rated forward current

D = duty cycle

T = period of frequency

t = diode "on" time

However, careful judgement should be used to ensure that the peak current does not exceed a level that will cause the bonding wires to open. The TIXL27 should not be exposed to peak pulses of current greater than 4 amperes with an appropriate duty cycle. Figure 6 shows typical peak power obtained when the device was operated at a frequency of 10 kHz with current levels of 1 ampere, 2 amperes and 4 amperes at respective duty cycles of 50%, 25%, and 12.5% – higher current pulses than equation (10) defines.

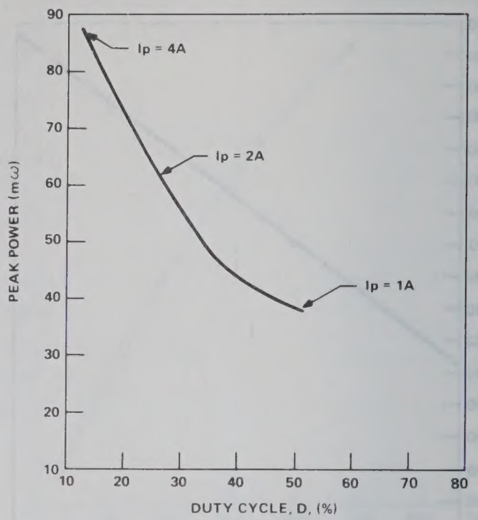


FIGURE 6. Typical Peak Power of TIXL 27 at 10 kHz with Various Peak Current Levels at Various Duty Cycles

Optical Design Considerations

Since the TIXL27 emits into such a large pattern (approximately 2π steradians), it is necessary to use some form of optics to collect and direct that portion of the optical power that will be used.

The amount of optical power collected can be determined quickly once the optics have been defined. The following is an example that illustrates the effect of the *f*/# of the lens on the power transmitted.

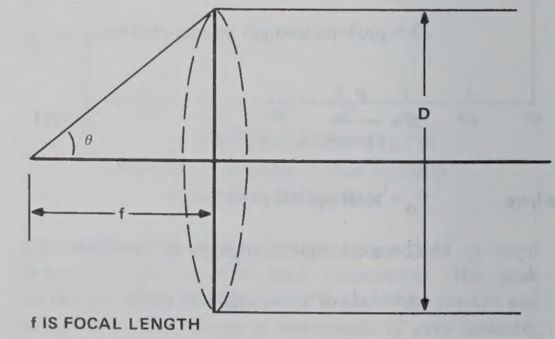


FIGURE 7. Typical Optical Collection Configuration

$$P_t = P_o \left(\frac{\Omega_c}{\Omega_e}\right) T_o = \qquad (11)$$

$$P_o \left(\frac{2\pi\,(1 - \text{Cos}\,\theta)}{2\pi}\right) T_o$$

where P_t = optical power transmitted in the beam of the collection optics.

Ω_c = the solid angle of collection in steradians.

Ω_e = the solid angle of emission in steradians.

T_o = the transmission efficiency of the lens.

θ = the half angle of the collection cone.

P_o = the total radiated optical power.

Table 1

f/#	θ (°)	$1 - \text{Cos}\,\theta$	P_t (mW)
1.0	26.6	0.1	1.5
1.4	19.6	0.06	0.8
2.0	14.0	0.03	0.45
2.8	10.2	0.02	0.3
4.0	7.0	0.01	0.15

TYPICAL APPLICATION DATA

Figure 8 shows an economical approach for modulating a TIXL27. This circuit features excellent bandwidth as well as high peak currents. Figures 9, 10, and 11 show the performance data for the circuit shown in Figure 8.

MECHANICAL DATA

The device is encapsulated and mounted on a stud header. The cathode is in electrical contact with the solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between stud and emitting element.

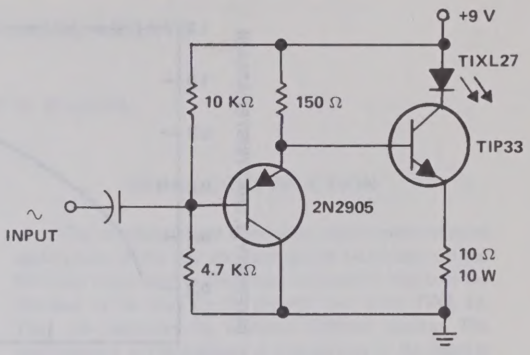


FIGURE 8. An Economical Circuit for Modulating a TIXL 27

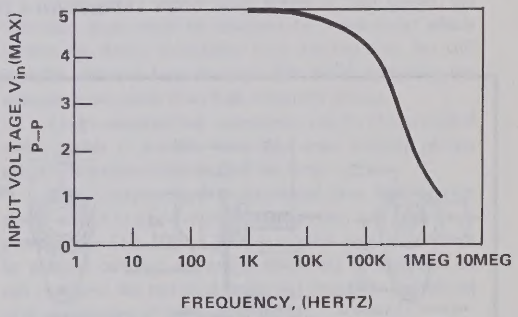


FIGURE 9. Maximum Frequency for Circuit in Figure 8

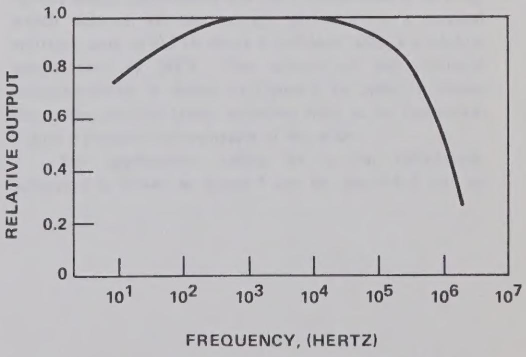


FIGURE 10. Frequency Response of LED and Module for Circuit in Figure 8

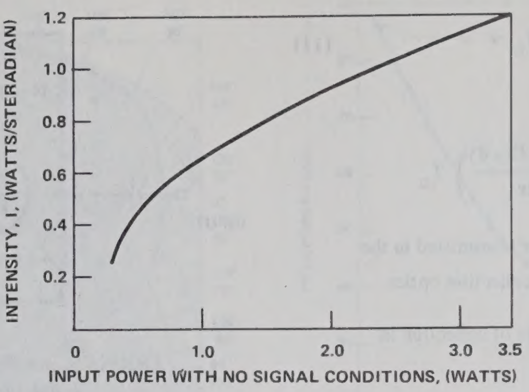
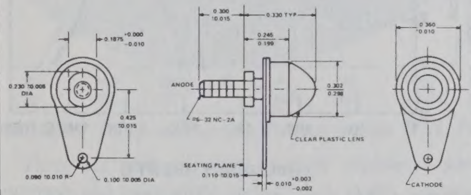


FIGURE 11. Intensity versus Input Power for Circuit in Figure 8 When it is Used with a f/# = 1.6 Lens Which has a 29 Millimeter Diameter


0.1875 +0.000 −0.010
0.230 ±0.005 DIA
0.425 ±0.015
0.090 ±0.010 R
0.100 ±0.005 DIA
0.300 ±0.015
0.330 TYP
0.245 / 0.199
0.302 / 0.298
ANODE
#6–32 NC–2A
CLEAR PLASTIC LENS
SEATING PLANE
0.110 ±0.015
0.010 +0.003 −0.002
0.360 ±0.010
CATHODE

NOTES:

A. The orientation of the lug in relation to the stud flats is not controlled.

B. Torque between stud and lug must be avoided. Flats are provided on the stud for tightening to heat sink.

ALL DIMENSIONS IN INCHES

FIGURE 12. Mechanical Specifications for TIXL 27

INJECTION LASER DIODE ARRAYS

R. Carroll and F.H. Doerbeck

Optoelectronics is one of the fastest growing segments of the electronics industry and it is a segment which is having exceptional impact upon equipment design. Solid state lamps emitting in the red and green portions of the spectrum, for example, are used as discrete lamps or as display arrays in new equipment, such as pocket calculators and digital clocks.

GaAs injection laser diodes, which were developed as early as 1962, still have not attained high volume application usage. But improvements in injection laser diodes, particularly for operation at room temperature, were achieved recently by utilization of heterostructure technology. This development eventually led to continuous wave operation at 300°K.

This discussion will concern itself with the design considerations of cooled GaAs laser diode arrays and present results obtained from the various kinds of arrays presently available.

ARRAY APPLICATIONS

Semiconductor injection laser diodes offer many properties which are useful for many systems applications: small size plus high power packing density, short rise and fall times, emission into a narrow beam angle, narrow linewidth, and adjustment of wavelength. The coherence of the emitted energy has not been included in this group because the electron magnetic energy emitted from several lasers which are not optically coupled does not have any definite phase relationship.

The primary application areas for laser diode arrays are those in which a monochromatic light source with short time constants and high peak power density is essential. Thus far, most of the applications have been military such as the determination of altitude and range, guidance or tracking of missiles, general night illumination and gated viewing illumination. Commercial applications include data transmission through fibre optics or open atmosphere, intrusion detection systems, auto collision warning systems and automatic camera focusing. Additional uses of injection laser diodes could be high speed photography and the high speed printing or copying of data on storage tape.

ARRAY CONSTRUCTION

The wavelength and duty cycle requirements of most applications in the past required cooled GaAs laser arrays. The laser chips used in the arrays discussed in this note are identical to the ones for the discrete laser diode TIXL 30. They are fabricated by a planar diffusion process. The improvement in performance in comparison to the discrete laser are due to better heatsinking.

For the construction of laser arrays consideration must be given to the following points: Duty cycle, heat transfer from the laser chip to the coldplate, space required for the laser, the electrical interconnections, and the emission beam angle.

Since arrays require series strings of laser diodes, the individual diode must be mounted on a submount which isolates the device electrically from the heatsink, but still provides efficient heat transfer. For 80°K operation the submounts are made from high resistivity silicon.

Lasers mounted on submounts can be characterized which makes it possible that only units meeting certain specifications are committed to the array.

Laser arrays may be categorized into high average power arrays (e.g., 10 watt average power) and high peak power arrays (e.g. 500 to 1000 watt peak power). It would be pointed out that the arrays which will be discussed do not represent the technical limits but should be considered only as examples of the state of the art.

High Average Power Arrays

High average power arrays have mainly been fabricated in a stair-step configuration using laminar subarrays, such as shown in Figure 1. Figure 2 depicts the optical source dimensions and the cross-section of an array which delivers 10 watt average power from a smallest emitting area of 0.230 times 0.160 inch with a coldplate temperature of 80°K. The scheme of the electrical interconnection is shown in Figure 3. In order to obtain short rise and fall times, striplines have to be employed. Figure 4 presents a photograph of the array.

For applications calling for a flat lightsource, subarrays as shown in Figure 5 can be assembled into an

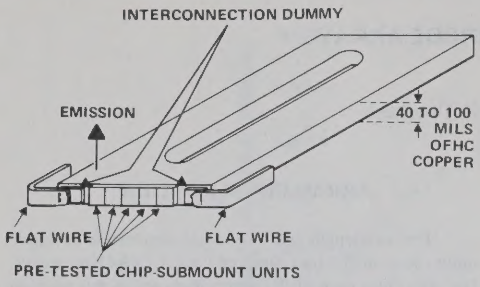


FIGURE 1. GaAs Injection Laser Diode Array Lamination

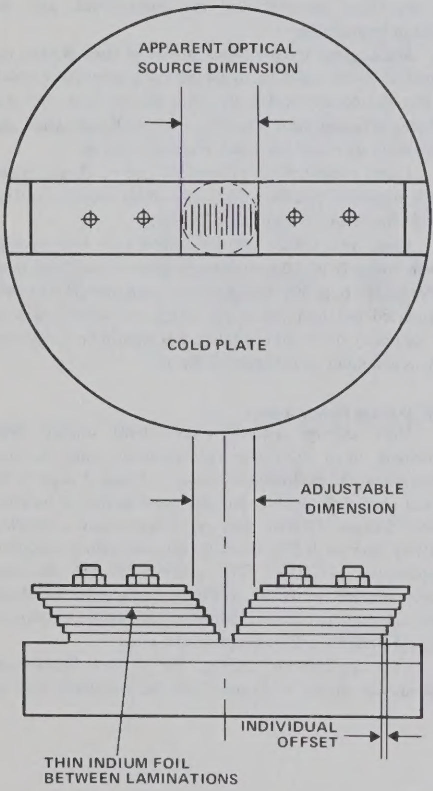

APPARENT OPTICAL SOURCE DIMENSION
COLD PLATE
ADJUSTABLE DIMENSION
INDIVIDUAL OFFSET
THIN INDIUM FOIL BETWEEN LAMINATIONS

FIGURE 2. Laminar GaAs Injection Laser Diode Array on Cold Plate

array as presented in Figure 6. It delivers 30 watts average power.

High Peak Power Arrays

For arrays with the emphasis on high peak power at low duty cycle the requirements for the heat transfer are less stringent. Therefore, solder connections can be replaced by epoxy connections except between the laser and the submount. As an example, we show in Figure 7 an array with 20 diodes, mounted on two copper stairstep blocks. At 80°K 200 watts of peak power are achieved from a light emitting area of 0.050 times 0.110 inch with conventional drive currents of approximately 20 amps. By employing laser diodes with antireflection coatings current and the output power levels can be doubled without exposing the lasers to catastrophic degradation.

OPTICS

The size of the optics necessary to collect all the energy emitted from a laser array is determined by the diagonal dimension of the array and the emission beam pattern. Typically more than 90% of the energy is contained within a total beam angle of 30°. To improve the beam uniformity, frequently an optical integrator is used. The exit plane of the integrator serves then as the planar light source for the following lens. This case is illustrated in Figure 8.

SUMMARY

This report is intended only to demonstrate some general capabilities in the field of cooled GaAs arrays. Presently the arrays are custom designed for particular operating temperature, during conditions and optical source size requirements. The basic design principles are also applicable to room temperature arrays. The choice of the submount material depends on the operating conditions, and includes BeO and, in the near future, diamond. The laser diode chips can be diffused lasers or single-hetero structure lasers.

Additional information concerning injection laser diodes and their applications is found in Texas Instruments Application Report Number CA-155, *Injection Laser Diode Fundamentals*, which is available on request.

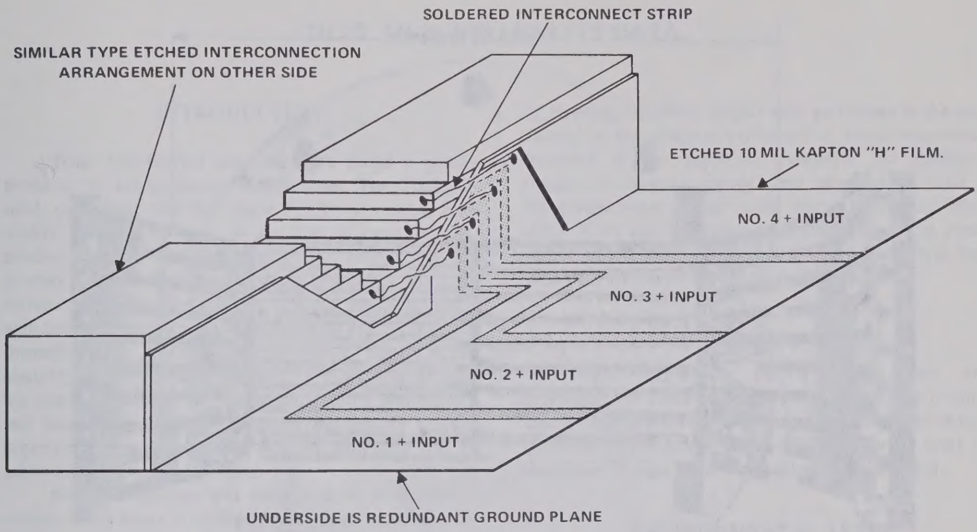

SOLDERED INTERCONNECT STRIP
SIMILAR TYPE ETCHED INTERCONNECTION ARRANGEMENT ON OTHER SIDE
ETCHED 10 MIL KAPTON "H" FILM.
NO. 4 + INPUT
NO. 3 + INPUT
NO. 2 + INPUT
NO. 1 + INPUT
UNDERSIDE IS REDUNDANT GROUND PLANE

FIGURE 3. Low Inductance Contacting Scheme for Laser Diode Arrays

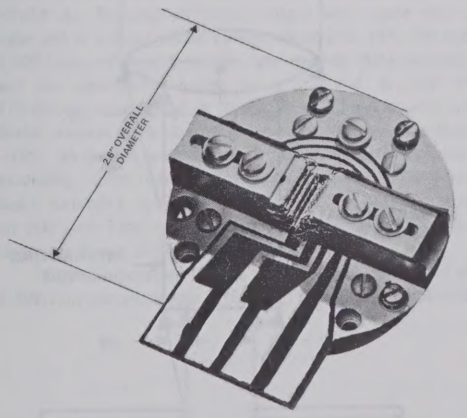

2.6" OVERALL DIAMETER

FIGURE 4. 10-Watt Laminar Injection Laser Diode Array

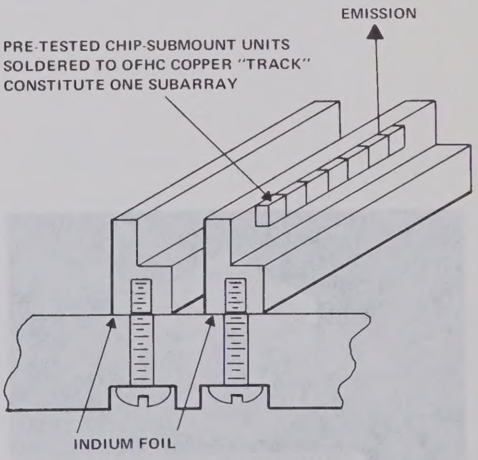

EMISSION
PRE-TESTED CHIP-SUBMOUNT UNITS SOLDERED TO OFHC COPPER "TRACK" CONSTITUTE ONE SUBARRAY
INDIUM FOIL

FIGURE 5. Flat-Field High-Power Injection Laser Diode Array Construction

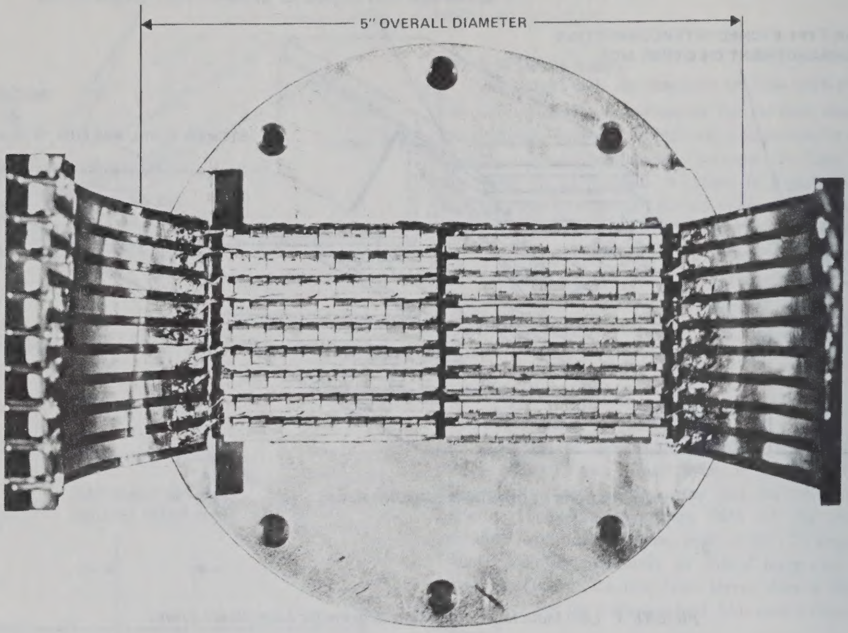
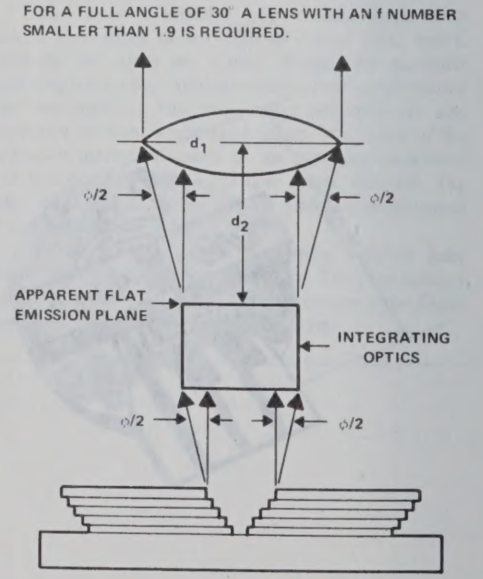

5" OVERALL DIAMETER

FIGURE 6. Flat-Field High-Power Injection Laser Diode Array


FOR A FULL ANGLE OF 30° A LENS WITH AN f NUMBER SMALLER THAN 1.9 IS REQUIRED.
d1
d2
ϕ/2
ϕ/2
APPARENT FLAT EMISSION PLANE
INTEGRATING OPTICS
ϕ/2
ϕ/2

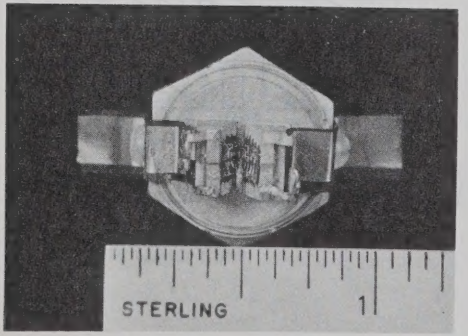


FIGURE 7. High Peak Power Density Array (80° K)

FIGURE 8. Basic Optics for Low Divergence (Well Collimated) Injection Laser Diode Array Illuminator

TIL23, TIL24 RELIABILITY DATA

INTRODUCTION

Texas Instruments has long been noted a quality producer of semiconductor components. The TIL23/24 solid state light emitting diode (LED) is another high quality, reliable addition to its line of optoelectronic products. It has been designed as a highly reliable, long life product capable of meeting demanding military and commercial needs. Quality control of these products begins with incoming inspection of raw materials and is continued throughout the manufacturing process as shown in the assembly-test flow diagram (Figure 1). Conscientious quality control practiced by the manufacturing organization and monitored at critical steps by the Quality Control organization assures that the designed reliability will be achieved in the finished product.

Since this product was announced in 1970, some 2 million device hours of reliability testing have been accumulated on un-graded, un-burned-in samples, and additional data is continuously being accumulated. This report summarizes, in graphical form, data on the operating life of TIL23/24 at 10, 30, and 50 mA at 25°C and 55°C. Results of various mechanical and temperature stress tests are also presented. Additional product data and copies of this brochure are available through your TI sales representative.

OPERATING LIFE TESTS

Room temperature (25°C) life tests were performed at 3 different current levels: 10 mA dc, 30 mA dc and 50 mA dc. Readings of power output were made with a solar cell in a short circuit current mode at 0, 168, 500 and 1,000 hours. Forward voltage was read at these intervals and no significant changes were observed. A total of 175 devices were tested at 10 mA dc or 30 mA dc with no device evidencing a change in power output greater than −10%. 96 devices were tested at 50 mA dc with 4 devices exceeding −20% reduction of power output (−27% worst case). Extended operating life tests at 25°C (4,000 hours) on 300 units have substantiated the extrapolated degradation rates shown in Figures 2, 3, and 4.

High temperature (55°C) life tests were performed at 3 different current levels: 10 mA dc, 30 mA dc, and 50 mA dc. Readings of power output were performed in the same manner as the readings performed at room temperature described in the preceding paragraph. No significant changes of forward voltage were observed. A total of 286 devices were tested with one catastrophic failure (ΔPO−97%) and 10 devices evidenced a change in power output greater than −20% (−39% worst case). Data from these tests are illustrated in Figures 5, 6, and 7.

STORAGE LIFE TESTS

High temperature (85°C) storage tests were performed for 1,000 hours on 172 units with an insignificant change in power output. Only two devices had changes of power output greater than −5% (−13% worst case). No significant changes of forward voltage were observed.

ENVIRONMENTAL TESTS

The tests listed in Figure 8 were performed on samples of the product with no catastrophic failures observed. It should be noted that the test conditions shown are not the ultimate strength of the product but represent the test requirements imposed by our customers. The ultimate strength of these devices is much higher in most cases. Inquiries concerning response to particular requirements should be addressed to your TI Sales Representative.

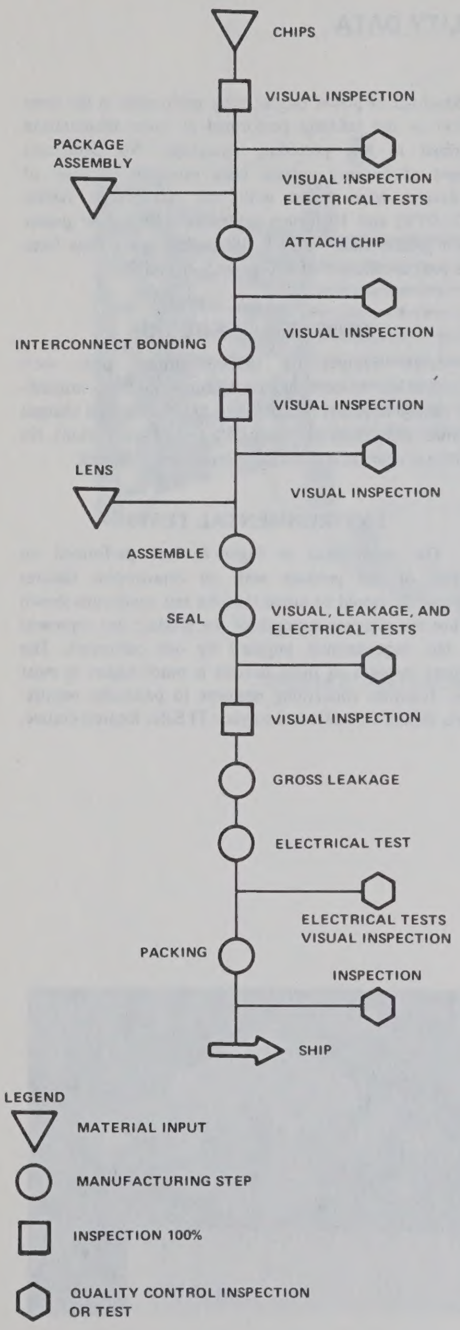

CHIPS
VISUAL INSPECTION
PACKAGE ASSEMBLY
VISUAL INSPECTION
ELECTRICAL TESTS
ATTACH CHIP
INTERCONNECT BONDING
VISUAL INSPECTION
VISUAL INSPECTION
LENS
VISUAL INSPECTION
ASSEMBLE
SEAL
VISUAL, LEAKAGE, AND ELECTRICAL TESTS
VISUAL INSPECTION
GROSS LEAKAGE
ELECTRICAL TEST
ELECTRICAL TESTS
VISUAL INSPECTION
PACKING
INSPECTION
SHIP
LEGEND
MATERIAL INPUT
MANUFACTURING STEP
INSPECTION 100%
QUALITY CONTROL INSPECTION OR TEST

FIGURE 1. TIL 23/24 Light Emitter Flow Diagram

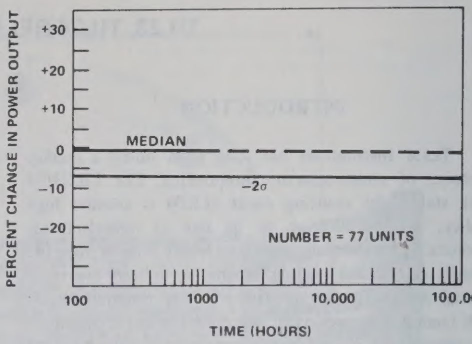


FIGURE 2. Change in Power Output as a Function of Operating Time at 10 mA dc, 25°C

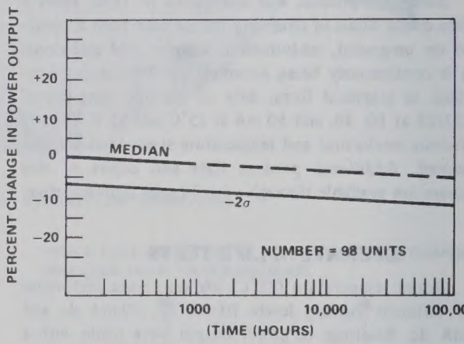


FIGURE 3. Change in Power Output as a Function of Operating Time at 30 mA dc, 25°C

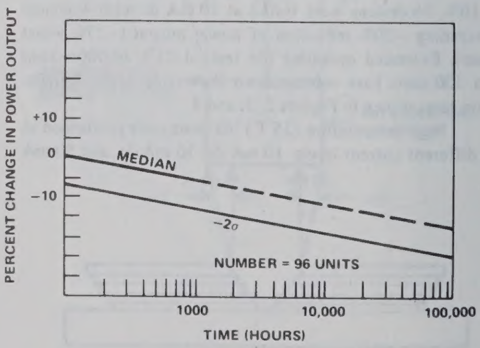


FIGURE 4. Change in Power Output as a Function of Operating Time at 50 mA dc, 25°C

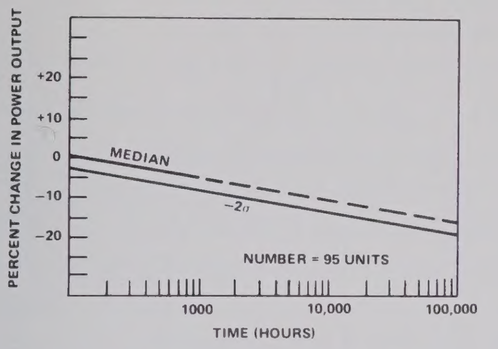


FIGURE 5. Change in Power Output as a Function of Operating Time at 10 mA dc, 55°C

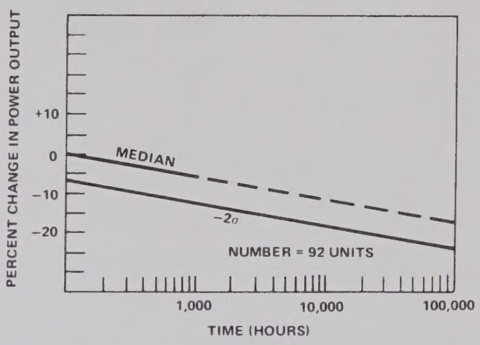


FIGURE 6. Change in Power Output as a Function of Operating Time at 30 mA dc, 55°C

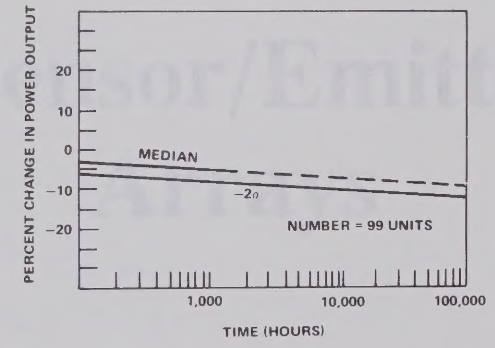


FIGURE 7. Change in Power Output as a Function of Operating Time at 50 mA dc, 55°C

MIL-STD-750 Test Method	Test	Quantity Tested	Failures (Catastrophic or Degradation)
1051	Temperature Cycle: 5 Cycles, 30 Minutes, −40°C to +100°C	110	0
1051	Temperature Cycle: 5 Cycles, 30 Minutes, −65°C to +150°C	50	0
1056	Thermal Shock: 5 Cycles, Condition A	50	0
1021	Moisture Resistance	50	0
2016	Shock, Impact: 1500 g, Z_1 Axis, 0.5 milliseconds	146	0
2056	Vibration, Variable Frequency: 20 g	146	0
2006	Constant Acceleration: 20 kg, 1 Min. Z_1	146	0
1071	Hermetic Seal: Test Condition E	390	1

FIGURE 8. Environmental Test Results

Sensor/Emitter Arrays

QUICK REFERENCE GUIDE
SENSOR/EMITTER ARRAYS

SENSOR-EMITTER ARRAYS QUICK REFERENCE GUIDE

DEVICE	TYPE	POWER OUTPUT @ $I_F = 50$ mA	V_F MAX @ $I_F = 50$ mA	I_L MIN @ $V_{CE} = 5$ V	I_C @ $I_F = 50$ mA $V_{CE} = 5$ V	$V_{CE(sat)}$ TYP @ $I_C = 2$ mA $I_F = 50$ mA	FEATURES
TIL131	Nine-element gallium arsenide LED array	0.4 mW	1.5 V				Nine TIL23's mounted on 0.1-inch centers. For paper tape readers.
TIL132	Nine-element phototransistor array			2 mA			Nine LS600's mounted on 0.1-inch centers in double-sided p-c board
TIL133	Nine-channel LED-phototransistor pair				2.5 mA to 10 mA	0.4 V	Consists of a TIL131 and a TIL132 with guaranteed channel performance
TIL134	Twelve-element gallium arsenide LED array	0.4 mW	1.5 V				Twelve TIL23's mounted on 0.250-inch centers. For reading punched cards
TIL135	Twelve-element phototransistor array			2 mA			Twelve LS600's mounted on 0.250-inch centers in double-sided p-c board
TIL136	Twelve-channel LED-phototransistor pair				2.5 mA to 10 mA	0.4 V	Consists of a TIL134 and TIL135 with guaranteed channel performance
TIL137	120-element phototransistor array			0.8 mA			Beam-lead phototransistors mounted in 10 X 12 matrix ceramic plug-in package

DEVICE	TYPE	ON-STATE COLLECTOR CURRENT			OFF-STATE COLLECTOR CURRENT		FEATURES
		MIN $I_{C(on)}$	@ I_F	@ V_{CE}	MAX $I_{C(off)}$	@ V_{CE}	
TIL138	One-channel transmissive assembly	1.6 mA 0.4 mA	35 mA 16 mA	0.5 V 0.5 V	25 nA	30 V	A TIL32 gallium arsenide LED and a TIL78 phototransistor mounted in plastic housing.
TIL139	One-channel reflective assembly	10 μA†	40 mA	5 V	25 nA	30 V	A TIL32 and a TIL78 mounted in a plastic housing.

† Reflective surface is Eastman Kodak (or equivalent) neutral white paper with 90% diffuse reflectance placed 0.150 inch from read head.

TYPES TIL131 THRU TIL133
9-ELEMENT ARRAYS AND 9-CHANNEL PAIR

TYPES TIL131, TIL132, TIL133
BULLETIN NO. DL-S 7111554, SEPTEMBER 1971

TIL131 . . . 9-ELEMENT GALLIUM ARSENIDE LED ARRAY
TIL132 . . . 9-ELEMENT PHOTOTRANSISTOR ARRAY
TIL133 . . . 9-CHANNEL PAIR

- Center-to-Center Spacing of 0.100 Inch for Tape Reading
- Reliable Solid-State Components
- LED's Eliminate Lamp-Filament-Sag Problems
- Spectrally Matched for Improved Performance
- Printed Circuit Board Construction Allows Precise Alignment

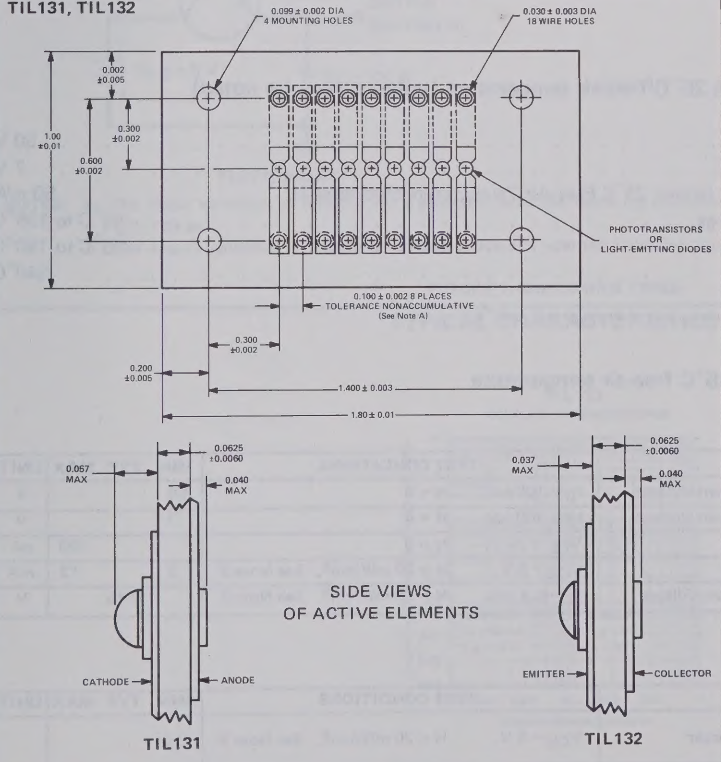
description

The TIL131 is an array of nine TIL23 gallium arsenide light-emitting diodes mounted in a printed circuit board. The TIL132 is an array of nine selected LS600 phototransistors. The TIL133 is a pair of selected arrays comprising a TIL131 and TIL132 and offering guaranteed channel performance.

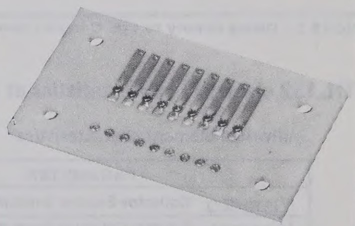
mechanical data

The printed circuit board material is glass-base FR-4, class II, 2-oz copper clad on both sides. The approximate weight of the TIL131 and TIL132 is 3.7 grams each.

TIL131, TIL132


0.099 ± 0.002 DIA
4 MOUNTING HOLES
0.030 ± 0.003 DIA
18 WIRE HOLES
0.002
±0.005
1.00
±0.01
0.300
±0.002
0.600
±0.002
PHOTOTRANSISTORS
OR
LIGHT-EMITTING DIODES
0.100 ± 0.002 8 PLACES
TOLERANCE NONACCUMULATIVE
(See Note A)
0.300
±0.002
0.200
±0.005
1.400 ± 0.003
1.80 ± 0.01
0.0625
±0.0060
0.057
MAX
0.040
MAX
0.037
MAX
SIDE VIEWS
OF ACTIVE ELEMENTS
CATHODE
ANODE
EMITTER
COLLECTOR
TIL131
TIL132

NOTE A: Tolerances shown on drawing apply for location dimensions of the mounting holes and the active elements. Tolerance of ±0.005 applies for location dimensions of wire holes.



TIL131 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Reverse Voltage	2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	100 mA
Operating Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (10 Seconds)	240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 1 mA/°C.

TIL131 operating characteristics of each element at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	$I_F = 50$ mA	0.4		1	mW
λ_{peak}	Wavelength at Peak Emission			0.93		μm
BW_λ	Spectral Bandwidth between Half-Power Points			500		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			35°		
V_F	Static Forward Voltage			1.25	1.5	V

TIL132 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Operating Free-Air Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (10 Seconds)	240°C

NOTE 2: Derate linearly to 125°C free-air temperature at the rate of 0.5 mW/°C.

TIL132 electrical characteristics at 25°C free-air temperature

individual element characteristics

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100$ μA, $H = 0$	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100$ μA, $H = 0$	7			V
I_D	Dark Current	$V_{CE} = 30$ V, $H = 0$			100	nA
I_L	Light Current	$V_{CE} = 5$ V, $H = 20$ mW/cm^2, See Note 3	2		12	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 0.4$ mA, $H = 20$ mW/cm^2, See Note 3		0.15		V

element matching characteristics

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$\frac{I_{L}min}{I_{L}max}$	Light Current Matching Factor	$V_{CE} = 5$ V, $H = 20$ mW/cm^2, See Note 3	0.5			

NOTE 3: Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TIL133 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Maximum ratings of TIL131 and TIL132 apply.

TIL133 electrical characteristics at 25°C free-air temperature

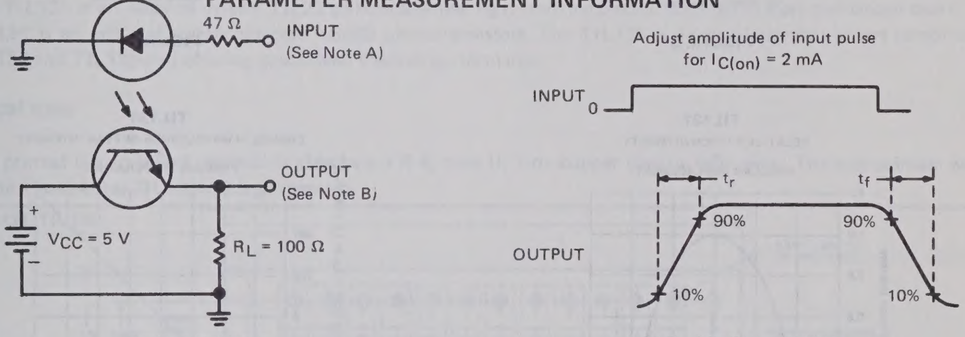
PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
I_C	Output Collector Current	$I_F = 50$ mA, $V_{CE} = 5$ V	2.5	4	10	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_F = 50$ mA, $I_C = 2$ mA		0.4	0.7	V

TIL133 switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_r	Rise Time	$V_{CC} = 5$ V, $I_{C(on)} = 2$ mA, $R_L = 100\ \Omega$, See Figure 1		1.5		μs
t_f	Fall Time			1.5		μs

†These parameters are measured at a lens-to-lens distance of 0.100 inch.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGES WAVEFORMS

NOTES: A. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 15$ ns, duty cycle ≈ 1%, $t_w = 100\ \mu s$.

B. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 12$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 20$ pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL133
COUPLING CHARACTERISTICS

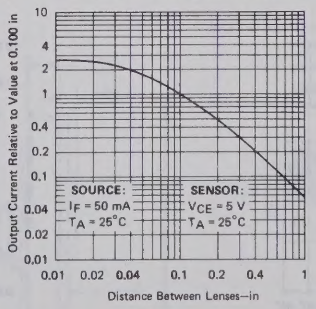


FIGURE 2

TYPICAL CHARACTERISTICS

TIL131
FORWARD CONDUCTION CHARACTERISTICS

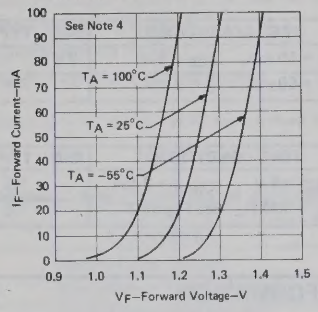


FIGURE 3

TIL131
RELATIVE POWER OUTPUT
vs
FORWARD CURRENT

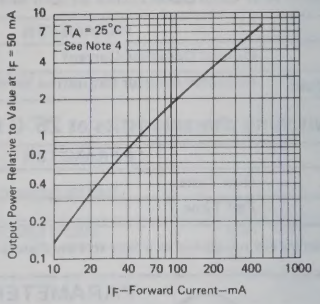


FIGURE 4

TIL131
RELATIVE PHOTON INTENSITY
vs
ANGULAR DISPLACEMENT

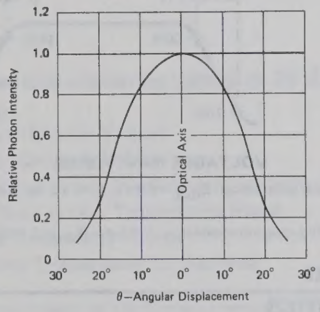


FIGURE 5

TIL131
CHANGE IN WAVELENGTH OF PEAK INTENSITY
vs
FREE-AIR TEMPERATURE

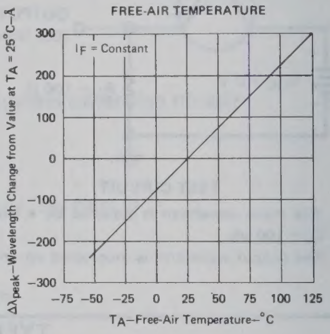


FIGURE 6

TIL132
NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

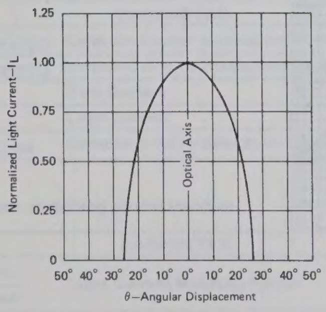


FIGURE 7

TIL132
DARK CURRENT
vs
FREE-AIR TEMPERATURE

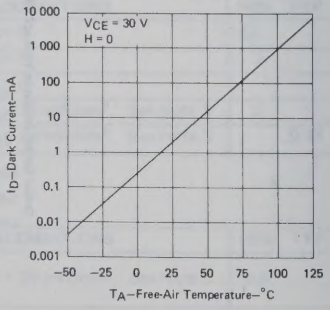


FIGURE 8

NOTE 4: These parameters were measured using pulse techniques t_w = 0.04 ms, duty cycle ⩽ 10%.

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TYPES TIL134 THRU TIL136
12-ELEMENT ARRAYS AND 12-CHANNEL PAIR

TYPES TIL134 THRU TIL136
BULLETIN NO. DL-S 7111561, SEPTEMBER 1971

6

TIL134 . . . 12-ELEMENT GALLIUM ARSENIDE LED ARRAY

TIL135 . . . 12-ELEMENT PHOTOTRANSISTOR ARRAY

TIL136 . . . 12-CHANNEL PAIR

- Center-to-Center Spacing of 0.250 Inch for Tape Reading
- Reliable Solid-State Components
- LED's Eliminate Lamp-Filament-Sag Problems
- Spectrally Matched for Improved Performance
- Printed Circuit Board Construction Allows Precise Alignment

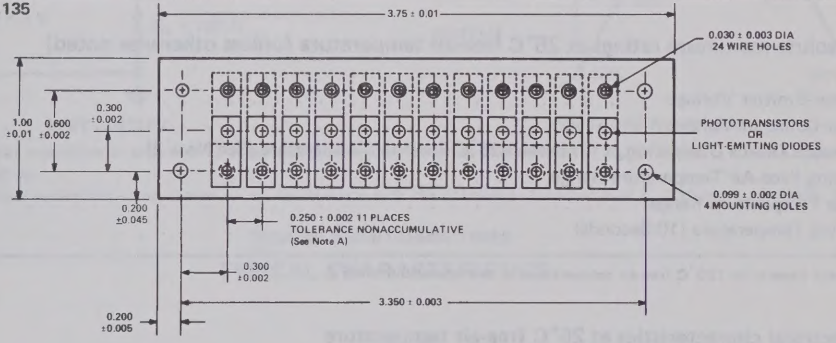
description

The TIL134 is an array of twelve TIL23 gallium arsenide light-emitting diodes mounted in a printed circuit board. The TIL135 is an array of twelve selected LS600 phototransistors. The TIL136 is a pair of selected arrays comprising a TIL134 and TIL135 and offering guaranteed channel performance.

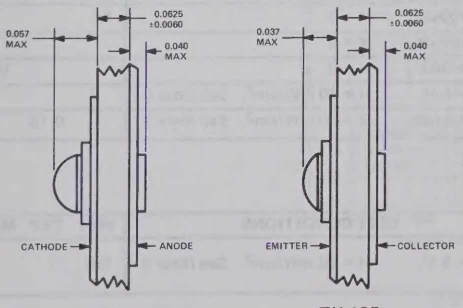
mechanical data

The printed circuit board material is glass-base FR-4, class II, 2-oz copper clad on both sides. The approximate weight of the TIL134 and TIL135 is 8.5 grams each.

TIL134, TIL135

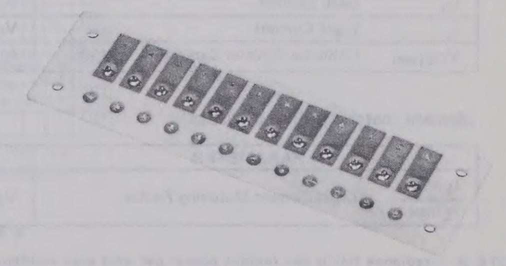

3.75 ± 0.01
0.030 ± 0.003 DIA
24 WIRE HOLES
1.00
±0.01
0.600
±0.002
0.300
±0.002
PHOTOTRANSISTORS
OR
LIGHT-EMITTING DIODES
0.099 ± 0.002 DIA
4 MOUNTING HOLES
0.200
±0.045
0.250 ± 0.002 11 PLACES
TOLERANCE NONACCUMULATIVE
(See Note A)
0.300
±0.002
3.350 ± 0.003
0.200
±0.005

NOTE A: Tolerances shown on drawing apply for location dimensions of the mounting holes and the active elements. Tolerance of ±0.005 applies for location dimensions of wire holes.


0.0625
±0.0060
0.057
MAX
0.040
MAX
CATHODE
ANODE
0.0625
±0.0060
0.037
MAX
0.040
MAX
EMITTER
COLLECTOR

TIL134 TIL135

SIDE VIEWS OF ACTIVE ELEMENTS



3/4 ACTUAL SIZE

TYPES TIL134 THRU TIL136
12-ELEMENT ARRAYS AND 12-CHANNEL PAIR

TIL134 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Reverse Voltage	2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	100 mA
Operating Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (10 Seconds)	240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 1 mA/°C.

TIL134 operating characteristics of each element at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	$I_F = 50$ mA	0.4		1	mW
λ_{peak}	Wavelength at Peak Emission			0.93		μm
BW_λ	Spectral Bandwidth between Half-Power Points			500		Å
θ_{HP}	Emission Beam Angle between Half-Power Points			35°		
V_F	Static Forward Voltage			1.25	1.5	V

TIL135 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Operating Free-Air Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (10 Seconds)	240°C

NOTE 2: Derate linearly to 125°C free-air temperature at the rate of 0.5 mW/°C.

TIL135 electrical characteristics at 25°C free-air temperature

individual element characteristics

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$,	$H = 0$	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$,	$H = 0$	7			V
I_D	Dark Current	$V_{CE} = 30$ V,	$H = 0$			100	nA
I_L	Light Current	$V_{CE} = 5$ V,	$H = 20\ mW/cm^2$, See Note 3	2		12	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 0.4$ mA,	$H = 20\ mW/cm^2$, See Note 3		0.15		V

element matching characteristics

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$\frac{I_{L}min}{I_{L}max}$	Light Current Matching Factor	$V_{CE} = 5$ V,	$H = 20\ mW/cm^2$, See Note 3	0.5			

NOTE 3: Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TIL136 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Maximum ratings of TIL134 and TIL135 apply.

TIL136 electrical characteristics at 25°C free-air temperature

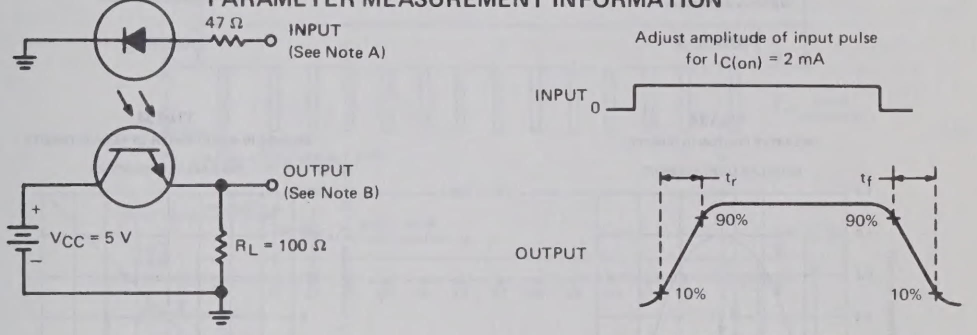
PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
I_C	Output Collector Current	$I_F = 50$ mA, $V_{CE} = 5$ V	2.5	4	10	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_F = 50$ mA, $I_C = 2$ mA		0.4	0.7	V

TIL136 switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_r	Rise Time	$V_{CC} = 5$ V, $I_{C(on)} = 2$ mA,		1.5		μs
t_f	Fall Time	$R_L = 100\ \Omega$, See Figure 1		1.5		μs

† These parameters are measured at a lens-to-lens distance of 0.100 inch.

PARAMETER MEASUREMENT INFORMATION



Adjust amplitude of input pulse for $I_{C(on)} = 2$ mA

TEST CIRCUIT

VOLTAGES WAVEFORMS

NOTES: A. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 15$ ns, duty cycle ≈ 1%, $t_w = 100\ \mu s$.

B. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL136
COUPLING CHARACTERISTICS

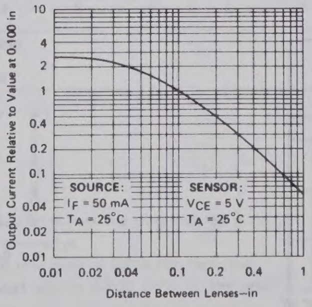


FIGURE 2

TYPICAL CHARACTERISTICS

TIL134
FORWARD CONDUCTION CHARACTERISTICS

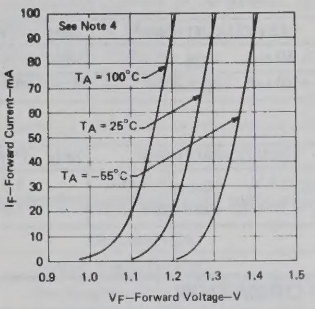


FIGURE 3

TIL134
RELATIVE POWER OUTPUT
vs
FORWARD CURRENT

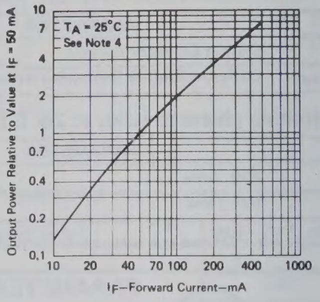


FIGURE 4

TIL134
RELATIVE PHOTON INTENSITY
vs
ANGULAR DISPLACEMENT

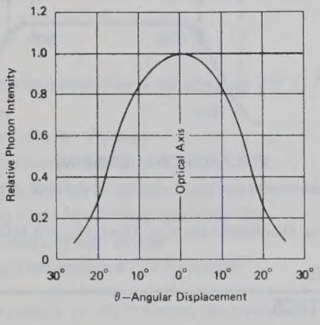


FIGURE 5

TIL134
CHANGE IN WAVELENGTH OF PEAK INTENSITY
vs
FREE-AIR TEMPERATURE

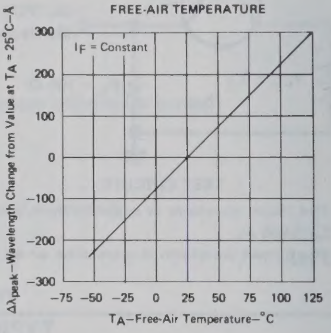


FIGURE 6

TIL135
NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

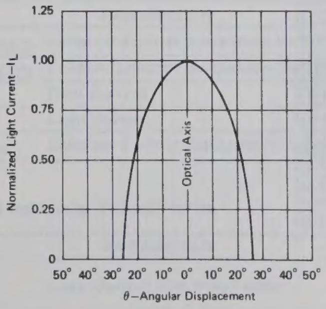


FIGURE 7

TIL135
DARK CURRENT
vs
FREE-AIR TEMPERATURE

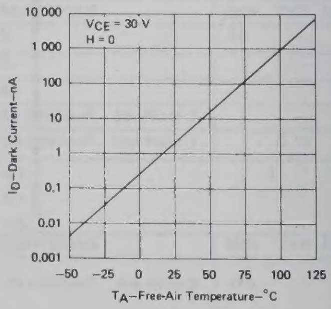


FIGURE 8

NOTE 4: These parameters were measured using pulse techniques t_w = 0.04 ms, duty cycle ⩽ 10%.

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TYPE TIL137
120-ELEMENT PHOTOTRANSISTOR ARRAY

TYPE TIL137
BULLETIN NO. DL-S 7111557, OCTOBER 1971

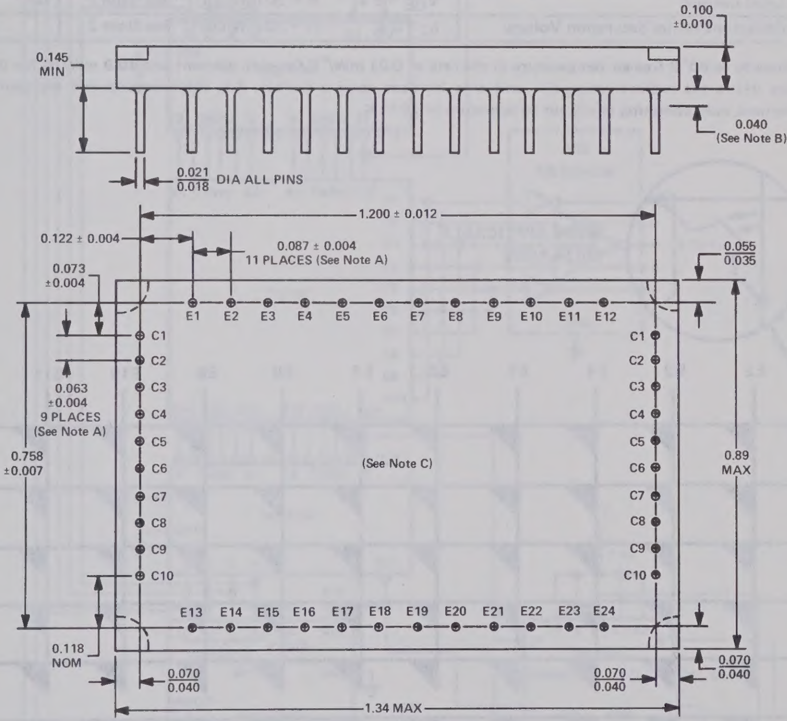
6

X-Y PHOTOTRANSISTOR ARRAY DESIGNED FOR STATIC READING OF INVENTORY CONTROL TICKETS AND OTHER APPLICATIONS

- 10 Rows on 0.063-Inch Centers by 12 Columns on 0.087-Inch Centers
- May Be Connected as a 5 X 24 or a 10 X 12 Matrix
- Beam-Lead Phototransistors with Apertures
- Ceramic Plug-In Package Allows Mounting into Printed Circuit Board Containing Interrogation and Read-Out Circuitry

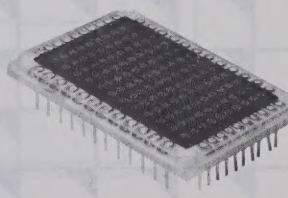
mechanical data

The array consists of beam-lead phototransistors bonded to a ceramic substrate which has connector pins mounted into it. An aperture plate is mounted over the array to reduce crosstalk. The assembly is then cast within a clear electrically nonconductive plastic compound.



0.100
±0.010
0.145
MIN
0.040
(See Note B)
0.021
0.018
DIA ALL PINS
1.200 ± 0.012
0.122 ± 0.004
0.087 ± 0.004
11 PLACES (See Note A)
0.055
0.035
0.073
±0.004
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10
0.063
±0.004
9 PLACES
(See Note A)
0.758
±0.007
(See Note C)
0.89
MAX
E13 E14 E15 E16 E17 E18 E19 E20 E21 E22 E23 E24
0.118
NOM
0.070
0.040
0.070
0.040
0.070
0.040
1.34 MAX

NOTES:
A. The location of the pins is measured where the pins emerge from the package. Tolerance is nonaccumulative.
B. Lead diameter is not controlled in this zone to allow for meniscus.
C. Phototransistor centers are located within 0.005 inch of the grid intersections of the pin centerlines.
D. All dimensions are in inches.



TYPE TIL137
120-ELEMENT PHOTOTRANSISTOR ARRAY

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

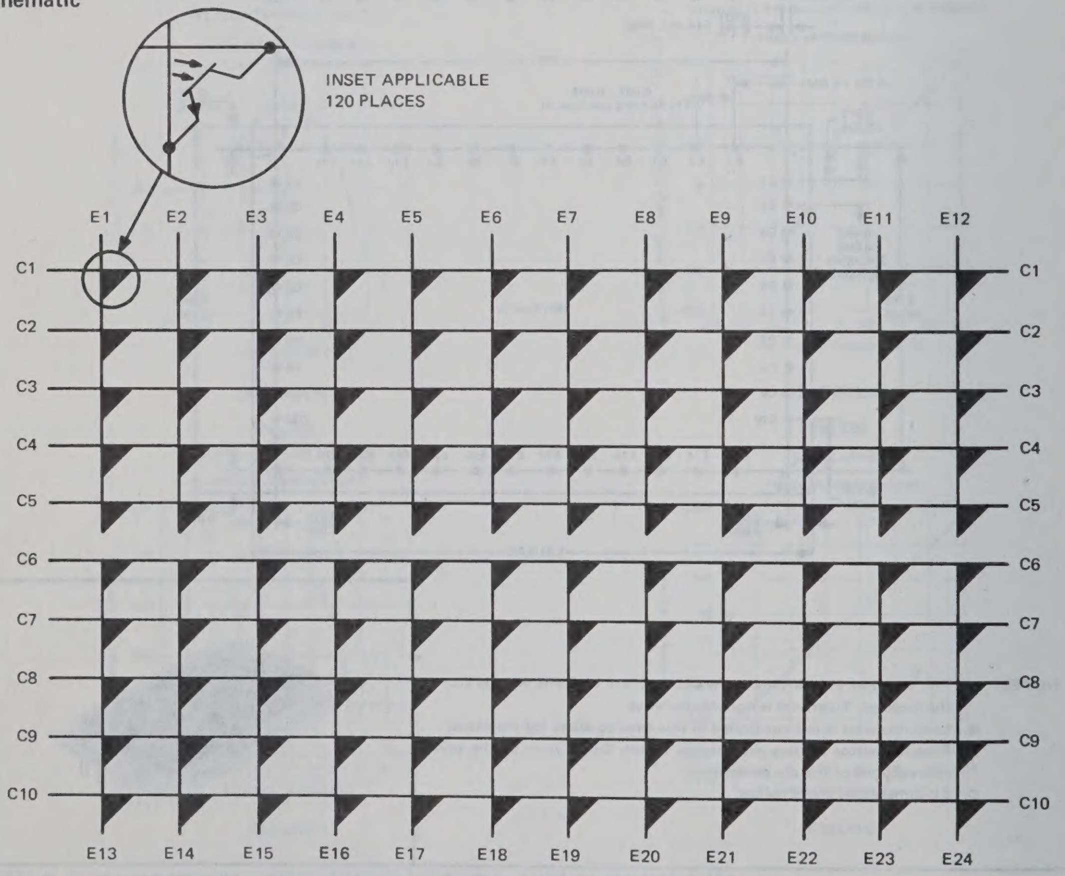
Collector-Emitter Voltage . . . . 10 V
Emitter-Collector Voltage . . . . 7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1):
  Each Element . . . . 50 mW
  Entire Array . . . . 600 mW
Operating Free-Air Temperature Range . . . . 0°C to 80°C
Storage Temperature Range . . . . −55°C to 100°C

electrical characteristics of each phototransistor at 25°C free-air temperature

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
I_D	Dark Current	V_{CE} = 10 V,	H = 0				100	nA
		V_{EC} = 7 V,	H = 0				100	
I_L	Light Current	V_{CE} = 5 V,	H = 20 mW/cm^2,	See Note 2	0.8	2		mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4,	H = 20 mW/cm^2,	See Note 2		0.3		V

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C for each element and 10.9 mW/°C for the entire array.
2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered linear-filament bulb operating at a color temperature of 2870 K.

schematic


INSET APPLICABLE
120 PLACES
E1
E2
E3
E4
E5
E6
E7
E8
E9
E10
E11
E12
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
E13
E14
E15
E16
E17
E18
E19
E20
E21
E22
E23
E24

TYPICAL APPLICATION DATA

The circuit shown below can be used to read inventory control tickets by addressing the TIL137 array in the 5-by-24 matrix configuration. Twenty-four serial address lines and five data lines are used to interrogate the matrix electrically for the data obtained optically from the ticket.

When a column is addressed by the active-low outputs of the SN74154 4-to-16-line decoders, any illuminated phototransistor in that column will cause a low logic level at the corresponding row output. This will be converted to a high logic level at the output of the SN54L04 buffers.

Note that lines 6, 7, 14, and 15 of the SN74154's are not connected to the TIL137. The SN7492 skips the binary equivalent of these counts thus synchronizing the divide-by-12 counter with the 16-count binary decoder.

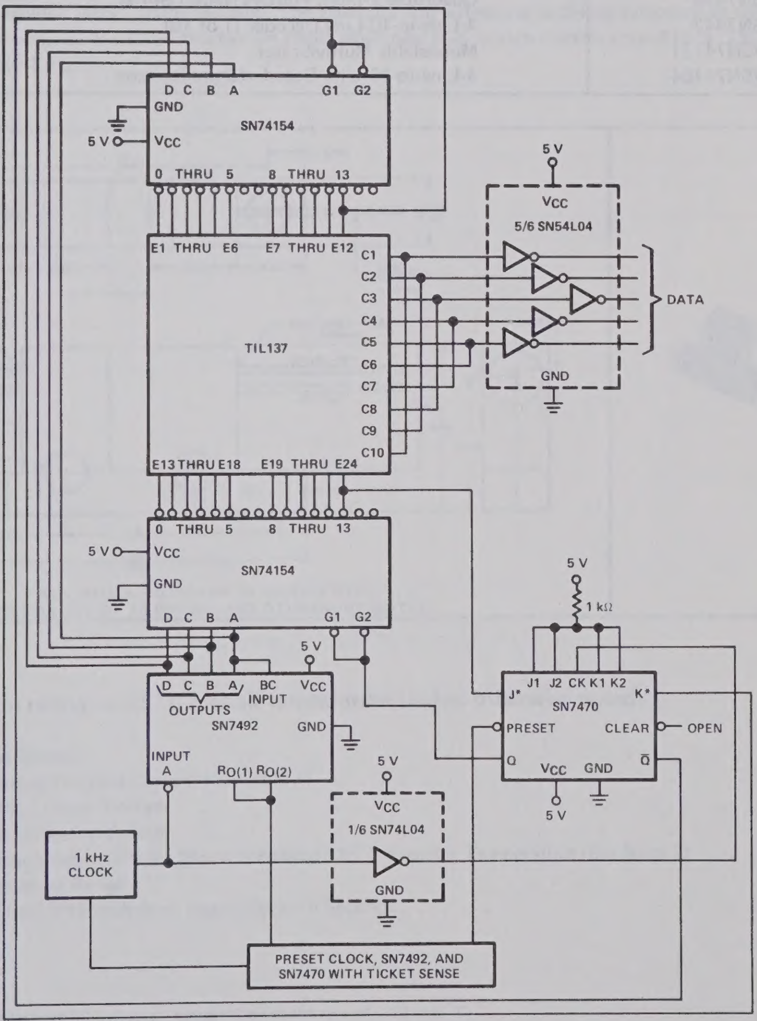

D C B A
G1 G2
GND
SN74154
5 V
VCC
0 THRU 5
8 THRU 13
E1 THRU E6
E7 THRU E12
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
TIL137
E13 THRU E18
E19 THRU E24
5 V
VCC
5/6 SN54L04
GND
DATA
0 THRU 5
8 THRU 13
5 V
VCC
SN74154
GND
D C B A
G1 G2
5 V
D C B A
BC INPUT
VCC
OUTPUTS
SN7492
GND
INPUT A
RO(1) RO(2)
5 V
1 kΩ
J1 J2 CK K1 K2
J*
K*
SN7470
PRESET
CLEAR
OPEN
Q
VCC
GND
Q̄
5 V
5 V
VCC
1/6 SN74L04
GND
1 kHz CLOCK
PRESET CLOCK, SN7492, AND SN7470 WITH TICKET SENSE

FIGURE 1—TIL137 USED AS A 24-BY-5-ADDRESS OPTICAL READER

TI cannot assume any responsibility for any circuits shown
or represent that they are free from patent infringement.

AS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME
ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

SENSOR/EMITTER ARRAY INTERFACE CHART

The following TI devices are commonly used in circuits for interfacing with sensor/emitter arrays. The interface chart is intended to be used for reference only since each circuit design is unique.

DEVICE TYPE	DESCRIPTION
2N3980	P-N Planar Unijunction Silicon Transistor
2N5449	N-P-N Epitaxial Planar Silicon Transistor
A5T2907	P-N-P Epitaxial Planar Silicon Transistor
SN5438/SN7438	Quadruple 2-Input Positive NAND Buffer
SN5442/SN7442	4-Line-to-10-Line Decoder (1 of 10)
SN54121/SN74121	Monostable Multivibrator
SN54154/SN74154	4-Line-to-16-Line Decoder/Demultiplexer

TYPE TIL138
SOURCE AND SENSOR ASSEMBLY

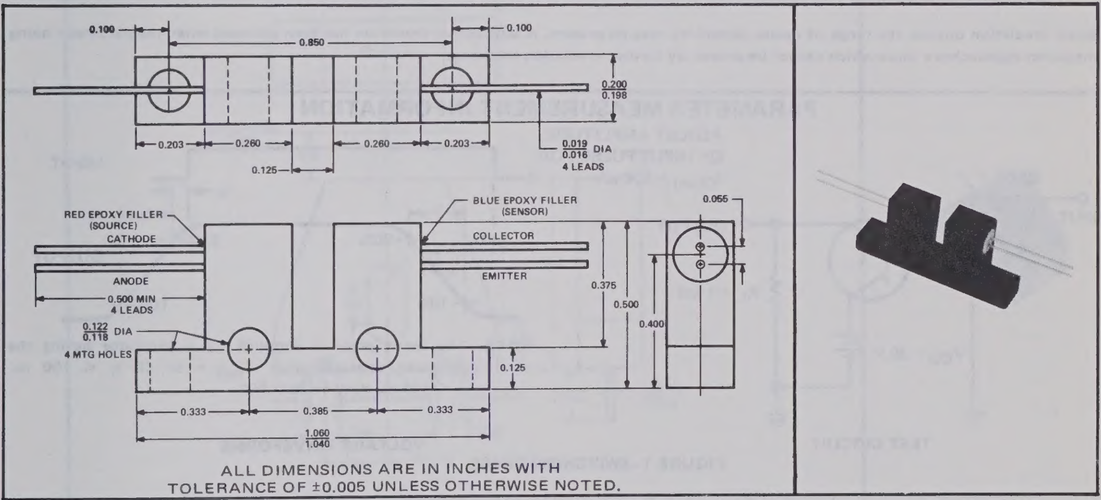
TYPE TIL138
BULLETIN NO. DL-S 7111558, SEPTEMBER 1971

OPTOELECTRONIC MODULE FOR TRANSMISSIVE SENSING APPLICATIONS

- Compatible With Standard DTL and TTL Integrated Circuits
- High-Speed Switching: $t_r = 1.5\ \mu s$, $t_f = 15\ \mu s$ Typical
- Designed for Base or Side Mounting
- For Sensing Applications such as Shaft Encoders, Sector Sensors, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators

mechanical data

The assembly consists of a TIL32 gallium arsenide light-emitting diode and a TIL78 n-p-n silicon phototransistor mounted in a molded ABS† plastic housing. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.5 grams.


0.100
0.850
0.100
0.200
0.198
0.203
0.260
0.260
0.203
0.125
0.019
0.016 DIA
4 LEADS
RED EPOXY FILLER
(SOURCE)
CATHODE
ANODE
0.500 MIN
4 LEADS
0.122
0.118 DIA
4 MTG HOLES
BLUE EPOXY FILLER
(SENSOR)
COLLECTOR
EMITTER
0.055
0.375
0.500
0.400
0.125
0.333
0.385
0.333
1.060
1.040

ALL DIMENSIONS ARE IN INCHES WITH TOLERANCE OF ±0.005 UNLESS OTHERWISE NOTED.

absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Source Reverse Voltage	2 V
Source Continuous Forward Current (See Note 1)	40 mA
Sensor Collector-Emitter Voltage	50 V
Sensor Emitter-Collector Voltage	7 V
Sensor Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.
2. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

†ABS thermoplastics are derived from acrylonitrile, butadiene and styrene.

TYPE TIL138
SOURCE AND SENSOR ASSEMBLY

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $I_F = 0$	7			V
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 30$ V, $I_F = 0$			25	nA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 0.5$ V, $I_F = 15$ mA	0.4	1		mA
		$V_{CE} = 0.5$ V, $I_F = 35$ mA	1.6	4		
V_F	Input-Diode Static Forward Voltage	$I_F = 15$ mA		1.15	1.5	V
		$I_F = 35$ mA		1.2		

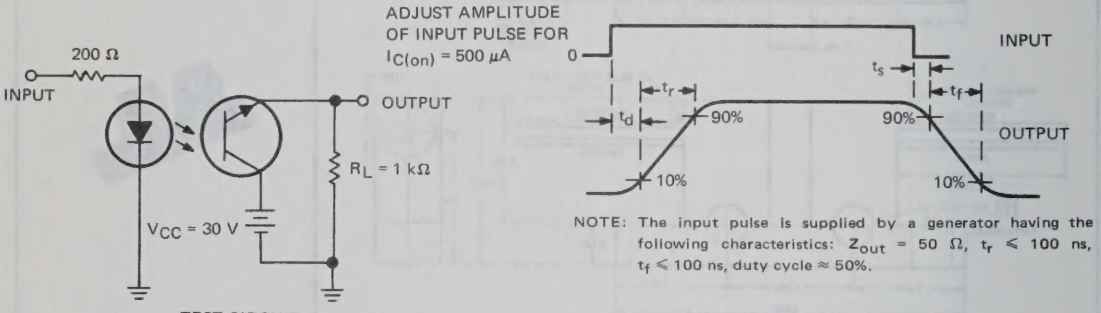
switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_d	Delay Time	$V_{CC} = 30$ V, $I_{C(on)} = 500\ \mu A$, $R_L = 1\ k\Omega$, See Figure 1		3		μs
t_r	Rise Time			1.5		μs
t_s	Storage Time			0.5		μs
t_f	Fall Time			15		μs

---

†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

PARAMETER MEASUREMENT INFORMATION



NOTE: The input pulse is supplied by a generator having the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 100$ ns, $t_f \leq 100$ ns, duty cycle ≈ 50%.

TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

PHOTOTRANSISTOR COLLECTOR CURRENT vs INPUT-DIODE FORWARD CURRENT

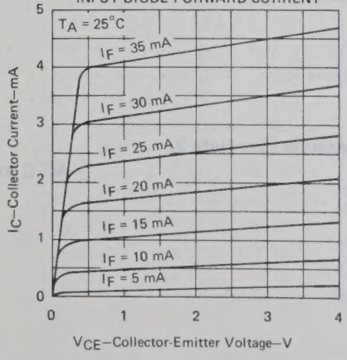


FIGURE 2

PHOTOTRANSISTOR COLLECTOR CURRENT vs INPUT-DIODE FORWARD CURRENT

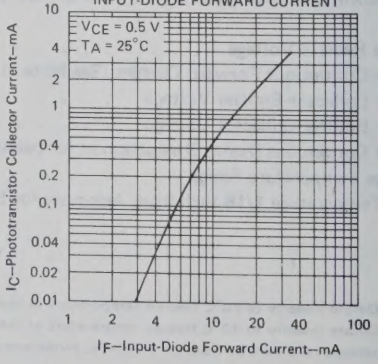


FIGURE 3

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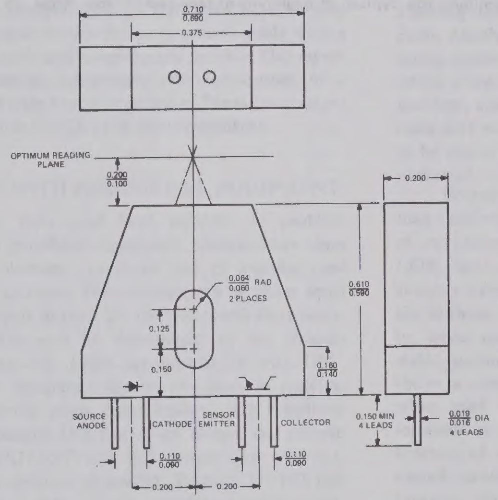
TYPE TIL139
SOURCE AND SENSOR ASSEMBLY

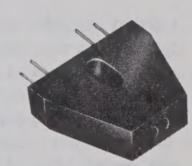
OPTOELECTRONIC MODULE FOR REFLECTIVE SENSING APPLICATIONS

- **Adaptable for Printed Circuit Board Mounting**
- **Designed for Sensing Applications such as Line Finders, Batch Counters, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators**

mechanical data

The assembly consists of a TIL32 gallium arsenide light-emitting diode and a TIL78 n-p-n silicon phototransistor mounted in a molded ABS† plastic housing. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.2 grams.


0.710
0.690
0.375
OPTIMUM READING PLANE
0.200
0.100
0.200
0.064
0.060
RAD
2 PLACES
0.610
0.590
0.125
0.150
0.160
0.140
SOURCE ANODE
CATHODE
SENSOR EMITTER
COLLECTOR
0.150 MIN
4 LEADS
0.019
0.016
DIA
4 LEADS
0.110
0.090
0.110
0.090
0.200
0.200



All dimensions are in inches with tolerance of ±0.005 unless otherwise noted.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Source Reverse Voltage	2 V
Source Continuous Forward Current (See Note 1)	40 mA
Sensor Collector-Emitter Voltage	50 V
Sensor Emitter-Collector Voltage	7 V
Sensor Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.
2. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

†ABS thermoplastics are derived from acrylonitrile, butadiene, and styrene.

TYPE TIL139
SOURCE AND SENSOR ASSEMBLY

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $I_F = 0$	7			V
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 30\ V$, $I_F = 0$			25	nA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 5\ V$, $I_F = 40\ mA$, See Note 3	10	15		μA
		$V_{CE} = 5\ V$, $I_F = 40\ mA$, See Note 4	5	7		
		$V_{CE} = 5\ V$, $I_F = 40\ mA$, See Note 5	100	130		
V_F	Input-Diode Static Forward Voltage	$I_F = 40\ mA$		1.2	1.6	V

† Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

NOTES: 3. Reflective surface is Eastman Kodak (or equivalent) neutral white paper with 90% diffuse reflectance placed 0.150 inch from read head.

4. Reflective surface is Mylar‡ (or equivalent) magnetic tape placed 0.150 inch from read head.

5. Reflective surface is 0.001-inch-thick aluminum foil, typical of beginning-of-tape/end-of-tape strips on magnetic tape surface, placed 0.150 inch from read head.

‡ Trademark of E. I. duPont

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OPTOELECTRONIC READ HEAD FOR PUNCHED CARDS AND TAPE

Winston Veazey

Because optical punched tape readers employing filament lamps are faster, quieter, smaller, less complex and have fewer moving parts than older mechanical readers, optical systems have dominated the respective market since shortly after their introduction. While these optical systems perform relatively well, they still have disadvantages, stemming mainly from filament aging. A better system, one eliminating filament-related problems and offering several other advantages, is a completely solid state read head. Recent advances in optoelectronics technology have made such a read head technically and economically feasible. This report discusses the design, advantages and applications of a completely solid state head comprised of Texas Instruments light emitting diode (LEDs) and phototransistors.

INTERFACE WITH PERIPHERAL EQUIPMENT

The solid state read head presents no problem interfacing with peripheral equipment. Standard size tapes are employed allowing continued use of existing tape equipment and software. Data outputs can be either serial or parallel and will depend on the associated electronics. The output levels will be determined by the channel amplifiers. Present-day LEDs are compatible with DTL, TTL, and MOS integrated circuits and discrete systems. Appropriate circuits allow compatibility with telephone levels where necessary. Other interface circuits can include TI series SN75107-SN75110 line drivers and receivers. Where electrical isolation is needed, TI series TIL107/108 optically coupled isolators are suitable. System noise, primarily noise caused from circulating ground currents, is eliminated with use of the isolators. These devices are also TTL compatible.

COMPARISON WITH FILAMENT LAMPS

Solid state light emitters have several important advantages over filament lamps used in read heads. One of the most important factors is increased reliability—the LEDs lifetime should be many times the life of the best filament lamp. In addition to the probable lifetime advantage, LEDs eliminate problems related to the filament as the lamp ages, such as filament sag. When the filament sags, light focuses incorrectly on the tape or card holes and consequently, errors in reading occur. Several methods have been used to try to overcome this disadvantage. One method has been to use the lamp at a very high intensity. This increased intensity produces enough light on the sensors and tends to minimize the effects of the sagging filament, but it results in shorter lamp life and difficulty in adjusting the threshold level for low opacity tapes and cards. Another effort to solve the problem has been to use spring tension on the filament. This type of lamp incorporating spring tension is expensive and mechanical resonance problems sometimes occur. By using LEDs, the problems associated with filaments can be eliminated and this appears to be one of the most desirable benefits of an all solid state read head.

Because LEDs are much more vibration resistant than filament lamps, they have stability over a wide range of environmental conditions which is another advantage LEDs have compared to filament lamps. The TIL23/24 emitters have temperature characteristics which are opposite to those of the LS600/TIL601 sensors, and consequently, when used as a pair, the TIL23/LS600 devices give stable outputs over a wide temperature range. Table 1 shows a comparison between tungsten lamps and LEDs when used with a phototransistor as sensor. It shows variation in output current of the phototransistor as a function of several parameters and illustrates the superior overall stability of LEDs compared to the stability of tungsten filament lamps. This stability results in much easier adjustment of the circuit and much more stable operating conditions.

LEDs require much lower power than the filament lamp resulting in much less heat dissipation in the head. Some filament lamps require as much as 15 watts of power as compared to less than 1/2 watt for nine LEDs. Because most of this power is dissipated as heat in the system, poor efficiency results. Since the required power is low, a relatively simple current driver/regulator can be utilized, with the necessary components in the driver being small and of low power. A discussion of the required circuitry appears later in this report.

Table 1. Comparison Between Tungsten Lamps and Light Emitting Diodes, Showing Variation in Output Current of Phototransistor

Spread Due To	Tungsten Lamp	LED
Temperature 0–75°C	3:1	1.5:1
Supply voltage ±5%	1.6:1	1.1:1
Aging 10,000 hours	2:1	1.5:1
Close match	8:1	4:1
Total spread	77:1	10:1

The small size of LEDs is another advantage. Because of its small size the light emitter can be placed in close proximity to the sensors, thus reducing the effect of any extraneous light which could cause reading errors. The LS600 phototransistors and TIL23/24 light emitters are in packages suitable for mounting on printed circuit boards. This packaging permits easy mounting and convenient interconnection with the rest of the head. Moreover, the physical compatibility eliminates any need for fiber optics, focus rod or external lens to focus the light on the sensors. In addition, there is no need for amplifier compensation which is often necessary when the light source is shorter than the tape or card width. The optical compatibility is illustrated in Figure 1. This graph shows the spectrum response of tungsten filament lamps, GaAs LEDs, Si sensors and the human eye. GaAs light emitters emit in the near infrared region, their peak output wavelength being very near that of Si sensors (phototransistors) resulting in efficient coupling between the devices.

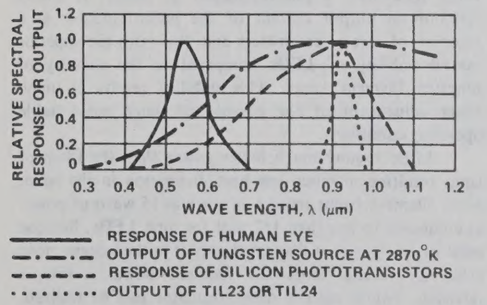


FIGURE 1. Relative Spectral Characteristics

PHYSICAL CHARACTERISTICS

In the design of an optical solid state read head, the mechanical configuration is very important. The sensor output, hence circuit requirements, are heavily dependent on the optical coupling characteristics. Representative coupling characteristics for TIL24 and LS600 devices are shown in Figure 2. This chart indicates that typical TIL24/LS600 device pairs are available which have outputs of 2 mA at a lens-to-lens spacing of 1/4 inch. These output levels are high enough to allow versatility in the amplifier/interface. Since the mechanical aspects of the system influence electrical output, much consideration should be given to the mechanical design. An important criterion related to electrical output is the system's contrast ratio. The contrast ratio is the ratio of "hole" output current to "no hole" output current of the phototransistor. For a good electrical design, this ratio should be as high as possible. Current ratios of 50:1 should make the required circuit design relatively simple. On the other hand, a low contrast ratio provides only a narrow range for the threshold level, making circuit design more difficult. Among the factors which affect the current ratio are 1) LED and sensor parameters, 2) lens-to-lens spacing of the LEDs and sensors, 3) placement of the tape or card between device pairs, 4) use of an aperture plate between pairs of devices, 5) tape opacity, and 6) optical crosstalk between channels. These factors are interrelated and will

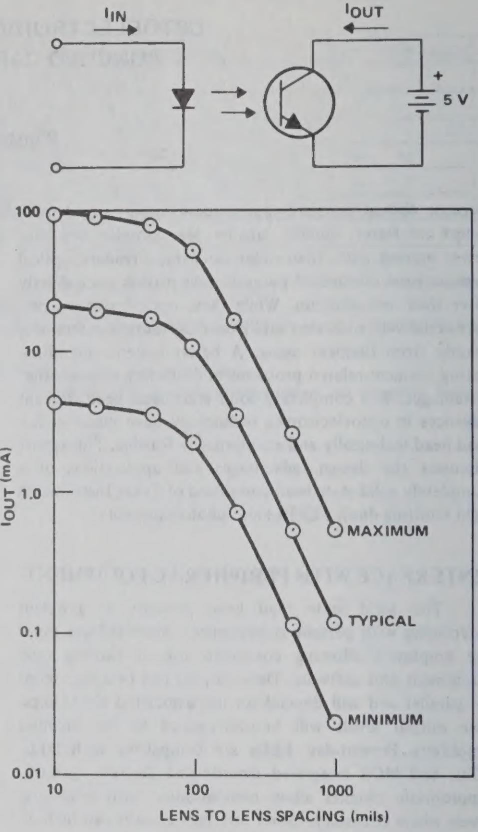


FIGURE 2. TIL24/LS600 Coupled Pairs. Expected Output Current for 50 mA Input Current.

affect current ratios. Each individual application will, to a certain extent, dictate some of the above factors. To get optimum results, use of device pairs rendering adequate output currents, an opaque aperature plate, high opacity tape, and a tube for each channel to prevent optical crosstalk are desired. Using an opaque aperture plate between the LEDs and phototransistors is probably the single most important factor in obtaining high contrast ratios for low opacity tapes. Contrast ratios versus LED current for various types of tape with several lens to lens spacings are shown in Figure 3. The data was taken using an aperture plate with holes of .035 inch diameter and having a separate tube for each channel to eliminate crosstalk. It is apparent that the oiled paper tapes are least desirable from a current ratio standpoint. This is to be expected since oiled paper tapes are the least opaque of the tapes commonly used in the industry. The graphs indicate that it is possible to obtain contrast ratios of 50:1 or greater for oiled paper tapes when using an aperture plate.

Good performance should result if the mechanical design insures adequate coupling when the tape or card is to be read. This involves the relative physical alignment concerning the LEDs sensors, aperture plate, and the tape or card being read.

CIRCUIT REQUIREMENTS

The many different tape and card reader applications can dictate various circuit requirements because of some specific mechanical or electrical restraint. It would be difficult, if not impossible, to try to design a circuit which would meet all requirements for all types of punched tape or card readers. However, some of the general problems which might be encountered in designing the circuitry necessary for a reader will be examined.

Many of the factors that affect the physical configuration influence the phototransistor output current, which in turn determines the channel amplifiers and related circuitry. The amplifiers must be capable of differentiating between "hole" and "no hole" currents and producing the level of output necessary to interface with peripheral equipment.

With sufficient sensor output currents, the devices can be compatible with TTL and DTL intergrated circuits. Figure 4-a represents one method by which phototransistors can be used with TTL. The sensor must be capable of sinking 1.6 milliamps at 0.8 volts to insure a logical zero on the input of the gate. The SN7413 is a Schmitt trigger type of NAND gate–its output will switch when the input reaches a set level, regardless of the rise time of the input signal. The result is clean, positive and fast switching at the output, without any oscillations which might otherwise appear at the output during the switching time. Use of the Schmitt trigger is desirable because typical TTL and DTL integrated circuits require inputs to switch in much less than one microsecond for clean outputs during rise and fall times and the switching times of typical phototransistors are greater than one microsecond.

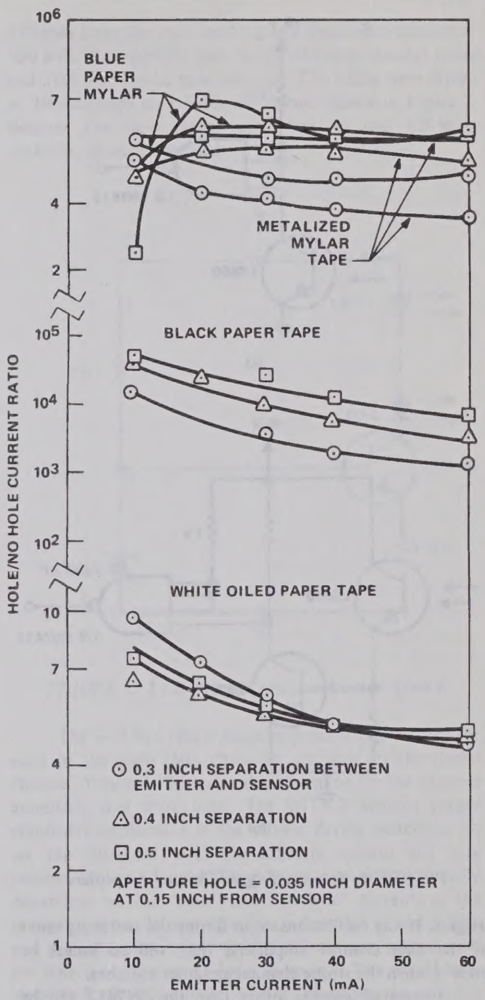


FIGURE 3. Different Contrast Ratios of White Oiled Paper, Black Paper and Metallized Mylar Tape at Various Currents of TIL 24/LS600 Coupled Pairs

Additional versatility can be obtained by making the amplifier much more sensitive. A simple circuit for achieving this is shown in Figure 4-b. The additional transistor gives another stage of amplification, increasing the sensitivity by approximately the h_{FE} of the transistor.

For increased versatility with the use of integrated circuits, the system can be designed so that only one Schmitt trigger is necessary, that being for the strobe amplifier. To use this technique effectively, the aperture hole for the strobe channel should be smaller than the holes for all the other channels. This size differential allows the data channel outputs to stabilize before the strobe amplifier

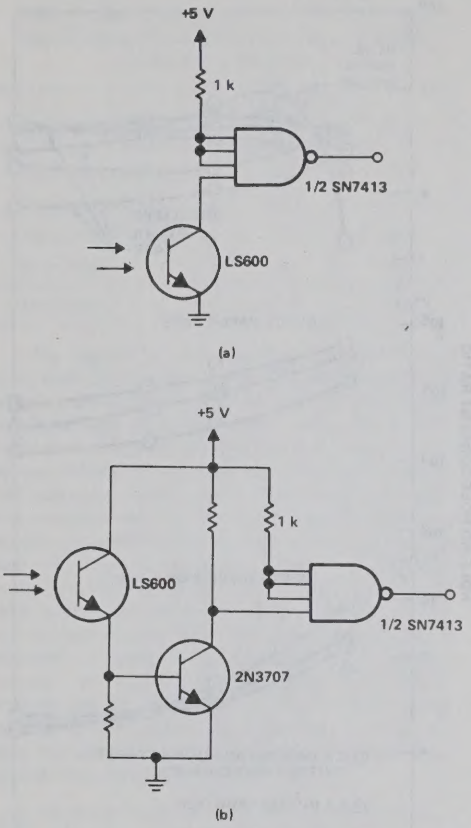

+5 V
1 k
1/2 SN7413
LS600
(a)
+5 V
1 k
LS600
1/2 SN7413
2N3707
(b)

FIGURE 4. Schmitt Trigger Channel Amplifiers

triggers. If any oscillations occur during the switching times of the data channel amplifiers, they will no longer be present when the strobe channel amplifier switches.

Integrated circuits other than the SN7413 can be used for the channel amplifiers. Circuits illustrating the use of several different devices are shown in Figure 5. The circuit shown in Figure 5-a uses only one gate of an SN7404 package. The sensor must be capable of sinking 1.6 mA at 0.8 volts–if not, the SN74L04 insures operation for a maximum sink current of 0.18 mA at 0.8 volts. The circuit in Figure 5-b makes use of a feedback resistor to provide faster switching–the output is inverted from that of Figure 5-a. Figures 5-c and 5-d show circuits which can be used where light levels may not be sufficient to insure 1.6 mA sensor current. Both have stages of gain for amplification before the gate. It should be noted that these circuits may have oscillations at the outputs during switching.

Other circuits can be designed to meet necessary requirements of channel amplifiers. Even if discrete

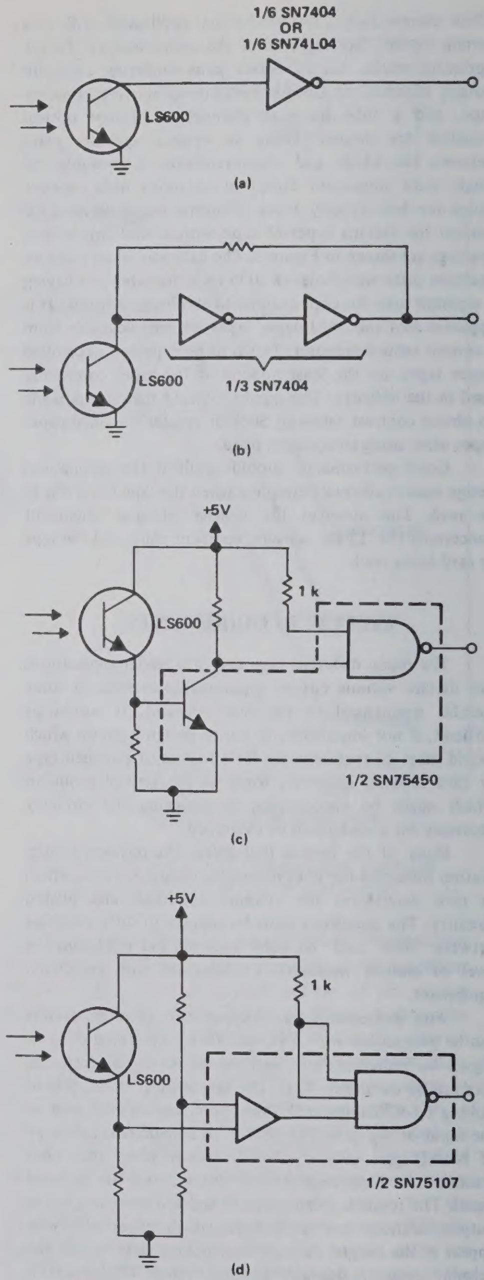

1/6 SN7404
OR
1/6 SN74L04
LS600
(a)
LS600
1/3 SN7404
(b)
+5V
1 k
LS600
1/2 SN75450
(c)
+5V
1 k
LS600
1/2 SN75107
(d)

FIGURE 5. Other Channel Amplifiers Using Integrated Circuits

components are used, it is desirable to use a Schmitt trigger arrangement to provide clean and positive switching at a predictable level.

The LEDs can be driven from a current source or voltage source, either in series or parallel. The most desirable method will be dependent on the system. In general, it is simpler and more efficient to drive the LEDs in series from a constant current source. Series connection insures the same current through all the LEDs and thus tends to maintain a more uniform light output. In addition, with the series connection, only two leads out of the LED array are necessary. For parallel connection of LEDs, a current limiting resistor in series with each LED must be used because of the difference in forward voltage drop of the devices.

Figure 6 illustrates a circuit to drive the LEDs in series from a constant current source which regulates variations in LED voltages and supply voltage. The LED current is determined by $(V_Z - 0.7)/R1$, where V_Z is the zener voltage. The zener diode voltage will be determined primarily by the supply voltage and the number of LEDs in series.

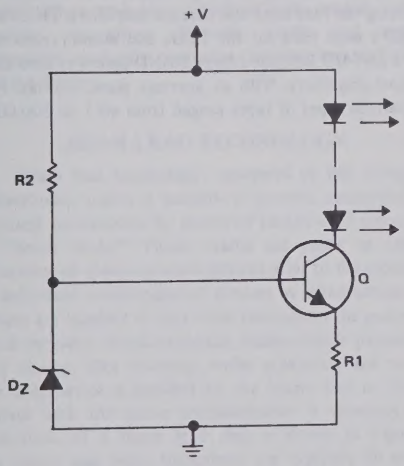


FIGURE 6. LED Driver/Regulator

DESCRIPTION OF A SOLID STATE READ HEAD IN AN ACTUAL APPLICATION

An off-the-shelf punched tape reader was bought and modified by replacing the read head and channel amplifiers. The tape reader was of the optical type with a filament lamp and photodiodes. Nine elements of LS600 phototransistors mounted on a small printed circuit board replaced the original photodiode array. This sensor array was mounted so that the phototransistor lenses were 150 mils from the tape. Since the LS600's and TIL24's have identical packages, they were mounted on similar printed circuit boards. The LEDs (TIL24's) were placed 150 mils from the tape resulting in a lens-to-lens spacing of 300 mils. An aperture plate with .045 inch channel holes and .035 inch strobe hole was used. The LEDs were driven at 10 milliamps each from the circuit shown in Figure 7. Because the tape reader only had +6 and +28 volts available, 28 volts was used.

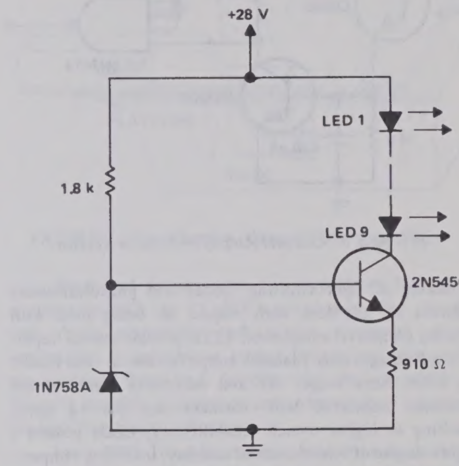


FIGURE 7. LED Driver/Regulator Used in System

The modified reader has nine parallel outputs, one for each of the eight data channels, and one for the strobe channel. Figure 8 illustrates the schematic for the channel amplifiers that were used. The SN7413 Schmitt trigger eliminates oscillations at the output during switching. To set the threshold level the collector resistor and base resistor can be adjusted. These resistor values are partially dependent on the "hole" and "no hole" currents of the phototransistor. It may have been desirable to use LEDs and phototransistors that were matched (have outputs that are within a given range for a set input). This would have simplified the adjustment of the amplifiers by insuring uniformity among the channels. Using matched devices is more desirable for lower contrast ratios, since the adjustment for these is more critical. Figures 3 and 4 show the typical contrast ratios which were achieved.

Since the tape reader has been used in a visual display system which requires slow strobe rates, speed of operation of this reader has not been a prime consideration.

SUMMARY

Optical punched tape and card readers have captured a large share of the respective market because of their many advantages over the older mechanical readers. This success, coupled with a reduction in prices of electronic components, has made the all solid state read head economically as well as technically practical and beneficial. A read head

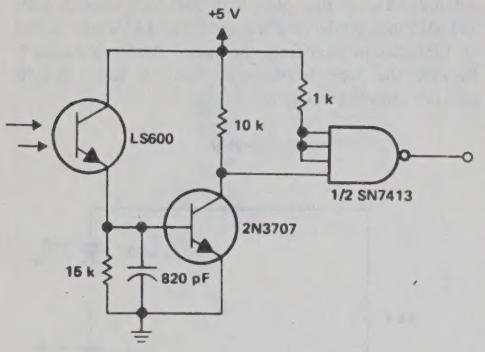


FIGURE 8. Channel Amplifier Used in System

consisting of light emitting diodes and phototransistors presents no problem with respect to being used with existing peripheral equipment. LEDs provide several important advantages over filament lamps for use in read heads: (1) LEDs have longer life and inherently eliminate the problems associated with filament sag due to aging, resulting in higher overall reliability. (2) LEDs possess a higher degree of environmental stability, including temperature and vibration stability. (3) LEDs have very low power requirements, dissipating less heat and having higher electrical efficiency. (4) The LEDs small size enables them to be placed in close proximity to the sensors, making the system smaller and less affected by extraneous light.

Physical configuration is very important in the performance of the overall system. The circuit requirements are dependent on the coupling characteristics of the LEDs and sensors. A high contrast ratio ("hole" current to "no hole" current) is desirable for simplicity in the circuit design. The use of an aperture plate between LEDs and sensors and elimination of optical crosstalk between channels are two factors which will help in achieving a high contrast ratio, especially for low opacity tapes.

Phototransistors can be compatible with integrated circuits. A Schmitt trigger integrated circuit (SN7413) allows simplicity in channel amplifier design to achieve clean and positive switching. A simple current source/regulator will suffice to drive the LEDs. Driving the LEDs in series from a constant current source provides uniformity in light output.

A standard optical tape reader was modified by replacing the read head and channel amplifiers. TIL24's and LS600's were used for the LEDs and sensors respectively and a SN7413 Schmitt trigger NAND gate was used in the channel amplifiers. With an aperture plate, contrast ratios for various types of tapes ranged from 40:1 to 500,000:1.

BEAM LEAD SENSOR ARRAYS

Texas Instruments beam-lead phototransistor arrays provide the designer maximum freedom and product reliability for applications in which a large number of phototransistors must be used. Instead of a design in which a large number of discrete phototransistor devices must be mounted and wired, the system can be designed so that only one TI sensor array need be employed.

In addition, TI beam-lead sensor arrays are advantageous for applications in which devices must be accurately spaced on centers too close for discrete packages and too far apart for an economical monolithic approach. A large number of sensors can be utilized in the array in a package size to meet most system requirements. (In fact, because of the beam-lead assembly techniques, the price per channel decreases as the number of channels increase.)

Because of their unique capabilities, these TI beam-lead sensor arrays are extremely beneficial in a wide range of applications such as card readers, badge readers, pattern-character recognition elements, credit card verifiers, holographic read-only memories, garment tag readers and position sensors.

BEAM LEAD TECHNOLOGY

Beam lead technology, conceived by Bell Telephone Laboratories, makes it possible to provide mechanical and electrical connections by means of cantilevered electrodes, or "beam leads." These beams are made as integral extensions of semiconductor devices prior to the separation of individual semiconductor devices in manufacture. The devices are handled in slice form throughout the processing which includes: initial oxidation, silicon-nitride passivation, gold plating, slice thinning, wafer separation and testing. The chip device is handled by the beams and no further contact with the active semiconductor is necessary. An illustration of a beam lead chip is shown in Figure 1. The silicon and beam thicknesses are typically 50 and 12 microns respectively.

The beam-lead phototransistor is a logical extension of technologies well established at Texas Instruments. The n-p-n transistor is prepared by conventional monolithic techniques with normal silicon spectral response. But the addition of silicon-nitride passivation and gold beam leads eliminates the need of encapsulating the device in a vacuum-tight package. The silicon-nitride passivation protects the junctions, while the beam leads provide the mechanical and electrical connections.

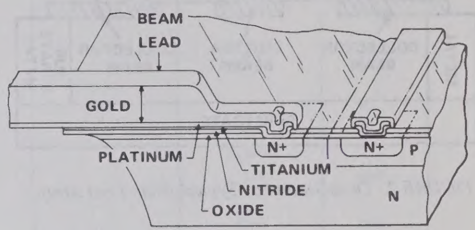


FIGURE 1. Cross-Section View of Beam Lead Chip

Beam-lead devices were first considered for use in conjunction with the TI MERA program in 1965. At that time both monolithic and hybrid integrated circuit approaches to microwave circuit fabrication were under examination. Beam-lead devices have the advantage of reducing parasitic capacitance and inductance so important for high frequency applications.

Since 1968 Texas Instruments has been a producer of circuits utilizing the beam-lead technique for various discrete and integrated devices for a variety of commercial and military applications. Such extensive design and production experience has enabled Texas Instruments to maintain its leadership position in the microwave and beam lead device marketplace.

When mounted on a metallized substrate, the chip device literally hangs by the beam leads shown in Figure 2. The devices can be mounted on metallized ceramic substrates utilizing thermocompression bonding techniques, or on printed circuit boards using conventional solder reflow methods. In either mode, the silicon nitride passivation provides the active junction protection required for reliable operation.

The beam-lead phototransistor is available on a custom basis in linear and x-y arrays. Array sizes are typically 50 to 1,000 devices mounted on printed circuit boards or ceramics substrates. Double-sided printed circuit boards with plated through-holes are the more popular embodiments.

The physical outline of beam lead phototransistors used for the custom arrays is shown in Figure 3. An actual array is shown in Figure 4. Overall device size, beam-tip to beam-tip, is 0.055 inch and permits construction of arrays with center-to-center sensor spacing as close as 0.060 inch. The accuracy of placement for an individual device is

BEAM LEAD SENSOR ARRAYS

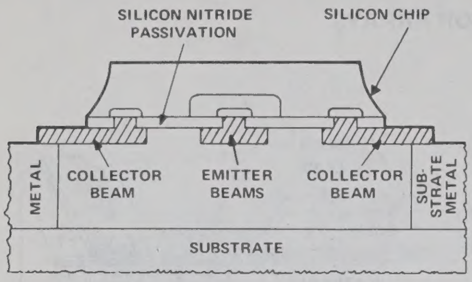


FIGURE 2. Cross-Section of Typical Beam Lead Array

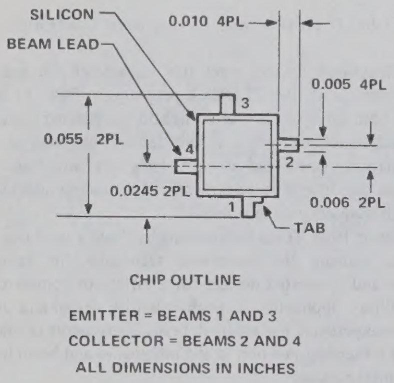


FIGURE 3. Dimensional Drawing of Typical Beam Lead Phototransistor

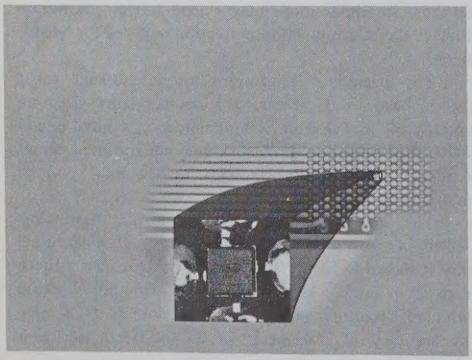


FIGURE 4. Typical Beam Lead Array (Individual chip shown enlarged in inset)

typically ±0.002 inch. The common connection of the emitter beams on one axis and the collector beams on the opposite axis permits x-y addressing of the sensors with a minimum of crossovers on the mounting medium. Other addressing requirements can be satisfied equally as well with structures and techniques available at Texas Instruments.

A complete array is generally supplied with protective coatings and mechanical covers, with optimum protection chosen for the particular application. The protective coating provides a moisture barrier. The mechanical protection may be metal, glass or plastic plates and provides protection from physical abuse.

The electrical characteristics of the beam-lead devices are comparable to those of standard phototransistors. The actual device characteristic limits are listed in Table 1.

For special applications the devices in each array can be light-response-matched in a maximum: minimum ratio of 2:1, or as specified. The value of light current at 3V bias allows interfacing with standard logic families with a minimum of external components.

An extensive program has been conducted by Bell Laboratories to evaluate the silicon nitride passivation and the integrity of the bond where the beam is connected to the silicon. Conclusions drawn from these tests indicate that silicon nitride surface passivation is a highly reliable sealant or sodium barrier, and the integrity of the beam lead interconnection system is superior to conventional ball, or stitch-bond techniques. Reliability data presented by Bell Laboratories and shown in Figure 5 comparing conventionally sealed SiO2 aluminum chips versus unencapsulated, nitride passivated beam-lead devices, indicates a factor of approximately three orders of magnitude reliability improvement for the beam-lead devices.

The beam-lead phototransistors, which use the same Si3N4Ti-Pt-Au contact system as the Bell Laboratories devices (mentioned previously), have been subjected to various environmental tests while mounted on printed circuit boards. Beam-lead phototransistors have surpassed 1,000 hours operating life at 55°C, 1,000 hours reverse bias at 150°C, temperature cycling from −40°C to 100°C, and 10-g vibration. By using a protective coating as a moisture barrier, beam-lead phototransistor arrays have exceeded 72 hours operating life at 85°C and 85% relative humidity. TI custom beam lead arrays are all coated to insure reliable operation for any printed circuit board application.

The beam-lead phototransistor offers a solution for medium density sensor arrays while allowing the designer maximum freedom and product assurance. Instead of mounting and wiring a large number of discrete devices, the user merely plugs in the TI array. The array is custom designed to fill a particular need and is delivered as an integral component ready to be placed in the system.

Table 1. Typical Beam Lead Sensor Electrical Characteristics at 25°C

Parameter	Test Conditions	Minimum	Maximum	Unit
I_L Light Current	V_{CE} = 5 V, H = 20 mW/cm^2 (See Note 1)	0.75		mA
I_D Dark Current	V_{CE} = 30 V, H = 0		0.1	μA
BV_{CEO} Breakdown Voltage	I_C = 0.5 mA	45.0		V
t_R Rise Time	V_{CC} = 10 V, I_L = 800 μA R_L = 1 k ohm		Typical 1.5	μsec
t_F Fall Time			15.0	μsec

NOTE:

IRRADIANCE (H) IS THE RADIANT POWER PER UNIT AREA INCIDENT UPON A SURFACE. FOR THIS MEASUREMENT THE SOURCE IS AN UNFILTERED TUNGSTEN LINEAR FILAMENT LAMP OPERATING AT 2870°K COLOR TEMPERATURE.

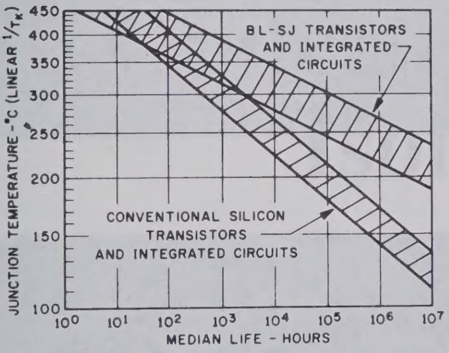
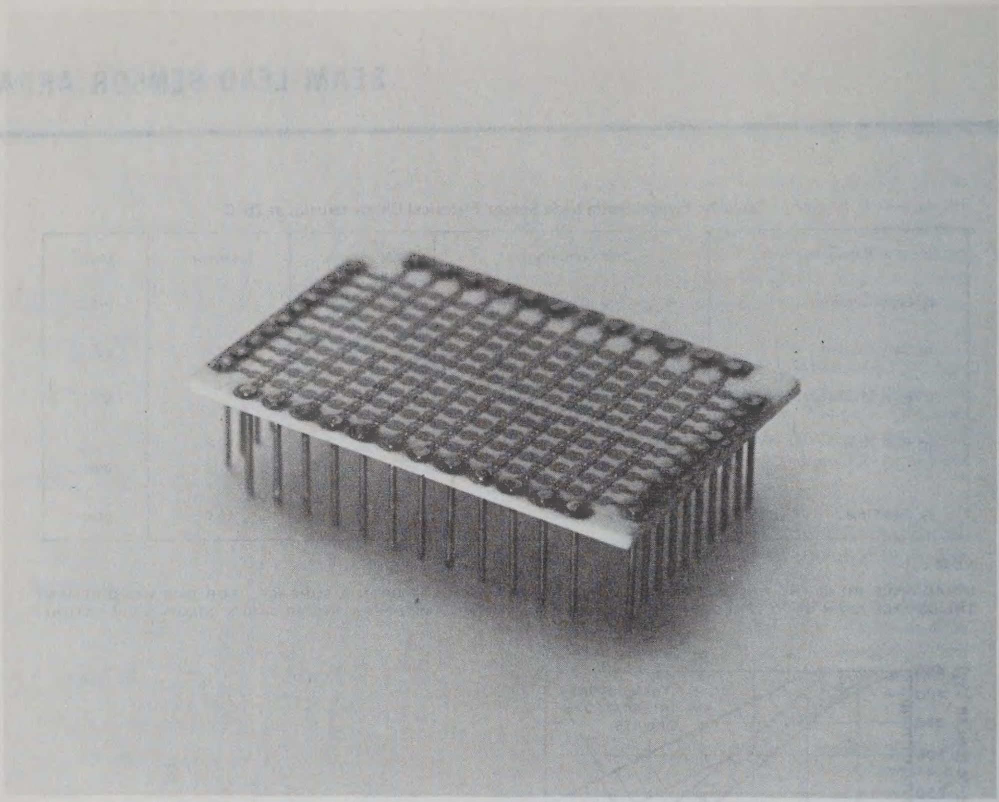
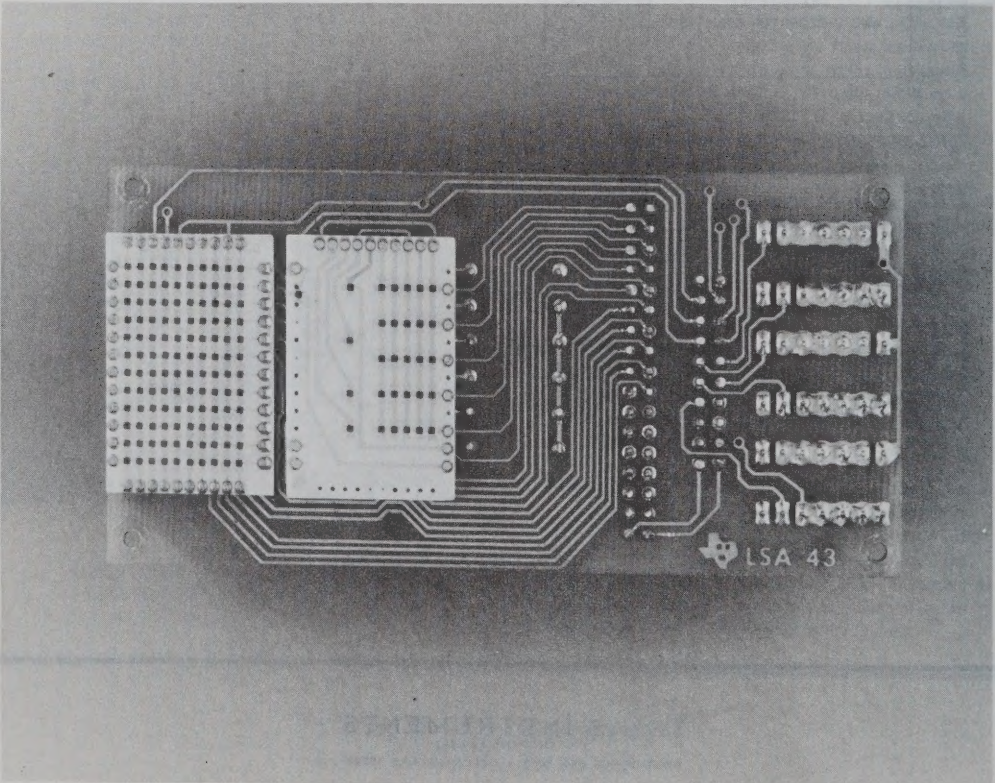


FIGURE 5. Reliability Comparison: Beam Lead Chip versus Conventional Transistor Chip

Data from an article "Reliability of Beam-Lead Sealed–Junction Devices" by D.S. Peck, Bell Telephone Laboratories, Proceedings–1969 Annual Symposium on Reliability, p. 201




LSA 43

Optically Coupled Isolators

7

OPTICALLY COUPLED ISOLATORS
QUICK REFERENCE GUIDE

DEVICE	PKG	ISOLATION VOLTAGE	ON-STATE COLLECTOR CURRENT $I_{C(on)}$		OFF-STATE COLLECTOR CURRENT $I_{C(off)}$		$V_{CE(sat)}$ MAX		V_F MAX		FEATURES
			MIN	@ I_F	MAX	@ V	V	@ I_F	V	@ I_F	
TIL102	V	±1 kV	2.5 mA	10 mA	100 nA	20	0.3	20 mA	1.3	10 mA	High input-to-output current transfer capability. Base lead connected for conventional transistor biasing. Hermetically sealed package.
			40 μA*	10 mA	0.1 nA*	20					
			TYP		TYP						
TIL103	V	±1 kV	10 mA	10 mA	100 nA	20	0.3	20 mA	1.3	10 mA	
			40 μA*	10 mA	0.1 nA*	20					
			TYP		TYP						
TIL107	5 N	±1 kV	0.5 mA	15 mA	25 nA	30	0.3	15 mA	1.5	15 mA	Hermetically sealed package. Compatible with standard DTL and TTL integrated circuits.
			1.6 mA	35 mA							
TIL108	5 N	±1 kV	1.6 mA	15 mA	25 nA	30	0.3	15 mA	1.5	15 mA	
			5 mA	35 mA							
TIL111	5 P	±1.5 kV	2 mA	16 mA	50 nA	10	0.4	16 mA	1.4	16 mA	Six-pin dual-in-line plastic package. Base lead provided for conventional transistor biasing.
			10 μA*	16 mA	20 nA*	10					
TIL112	5 P	±1.5 kV	0.2 mA	10 mA	100 nA	5	0.5	50 mA	1.5	10 mA	
			2 μA*	10 mA	50 nA*	5					

DEVICE	PKG	ISOLATION VOLTAGE	0°C to 70°C INPUT-TO-OUTPUT CHARACTERISTICS	V_F TYP		TYPICAL SWITCHING CHARACTERISTICS ns				FEATURES
				V	@ I_F	t_r	t_d	t_s	t_f	
TIXL104	2T	±100 V	$V_{out(0)} \leq 0.5$ @ $I_{in} = 10$ mA $V_{out(1)} \geq 2.5$ V @ $I_{in} = 0.5$ mA	1.2	10 mA	400	300	500	100	Opto pulse amplifier with inverted output. RTL compatibility. Hermetically sealed flat pack.
TIXL105	2T	±100 V	$V_{out(0)} \leq 0.5$ V @ $I_{in} = 0.5$ mA $V_{out(1)} \geq 5$ V @ $I_{in} = 10$ mA	1.2	10 mA	200	600	500	100	Opto pulse amplifier with non-inverted output. DTL and TTL compatibility.
TIXL106	2T	±100 V	All of the above	1.2	10 mA					Opto pulse amplifier with RTL, DTL, and TTL compatibility.

DEVICE	PKG	ISOLATION VOLTAGE	ON-STATE COLLECTOR CURRENT $I_{C(on)}$		OFF-STATE COLLECTOR CURRENT $I_{C(off)}$		$V_{CE(sat)}$		V_F MAX		FEATURES
			MIN	@ I_F	MAX	@ V	V	@ I_F	V	@ I_F	
TIXL109	4 I	±5 kV	250 μA	35 mA	500 nA	5	0.2 TYP	35 mA	1.9	35 mA	High input-to-output voltage isolation.
TIXL113	5 P	±1.5 kV	2.5 mA	2.5 mA	100 nA	10	1 MAX	10 mA	1.5	10 mA	Darlington-connected photoxtr output.

*Photodiode operation

TYPES TIL102, TIL103
OPTICALLY COUPLED ISOLATORS

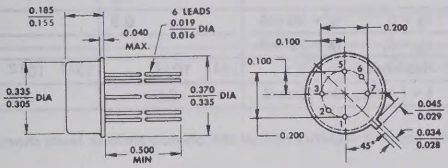
TYPES TIL102, TIL103
BULLETIN NO. DL-S 7011388, SEPTEMBER 1970

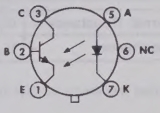
GALLIUM ARSENIDE DIODE LIGHT SOURCE OPTICALLY COUPLED TO A HIGH-GAIN N-P-N SILICON PHOTOTRANSISTOR

- Photon Coupling for Isolator Applications
- Base Lead Provided for Conventional Transistor Biasing
- High Overall Current Gain . . . 1.5 Typ (TIL103)
- High-Gain, High-Voltage Transistor . . . h_{FE} = 500 Typ (TIL103), $V_{(BR)CEO}$ = 35 V Min
- High-Voltage Electrical Isolation . . . 1-kV Rating
- Stable over Wide Temperature Range

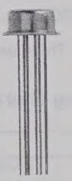
mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





NC — NO INTERNAL CONNECTION



Dimensions without tolerance designate true position. Leads having maximum diameter (0.019″) measured in gaging plane 0.054″ +0.001″ −0.000″ below the seating plane of the device shall be within 0.007″ of their true positions relative to a maximum-width tab.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1 kV
Collector-Emitter Voltage	35 V
Collector-Base Voltage	35 V
Emitter-Base Voltage	4 V
Input Diode Reverse Voltage	2 V
Input Diode Continuous Forward Current at (or below) 65°C Free-Air Temperature (See Note 1)	40 mA
Continuous Collector Current	50 mA
Continuous Transistor Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	300 mW
Storage Temperature Range	−55°C to 125°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. Derate linearly to 125°C free-air temperature at the rate of 0.67 mA/°C.
2. Derate linearly to 125°C free-air temperature at the rate of 3 mW/°C.

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER			TEST CONDITIONS	TIL102			TIL103			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 100\ \mu A$, $I_E = 0$, $I_F = 0$	35			35			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 1\ mA$, $I_B = 0$, $I_F = 0$	35			35			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 100\ \mu A$, $I_C = 0$, $I_F = 0$	4			4			V
I_R	Input Diode Static Reverse Current		$V_R = 2\ V$			100			100	µA
$I_{C(on)}$	On-State Collector Current	Phototransistor Operation	$V_{CE} = 5\ V$, $I_B = 0$, $I_F = 10\ mA$	2.5	6		10	15		mA
		Photodiode Operation	$V_{CB} = 5\ V$, $I_E = 0$, $I_F = 10\ mA$		40			40		µA
$I_{C(off)}$	Off-State Collector Current	Phototransistor Operation	$V_{CE} = 20\ V$, $I_B = 0$, $I_F = 0$		6	100		6	100	nA
			$V_{CE} = 20\ V$, $I_B = 0$, $I_F = 0$, $T_A = 100°C$		4			4		µA
		Photodiode Operation	$V_{CB} = 20\ V$, $I_E = 0$, $I_F = 0$		0.1			0.1		nA
h_{FE}	Transistor Static Forward Current Transfer Ratio		$V_{CE} = 5\ V$, $I_C = 10\ mA$, $I_F = 0$		300			500		
V_F	Input Diode Static Forward Voltage		$I_F = 10\ mA$			1.3			1.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 2.5\ mA$, $I_B = 0$, $I_F = 20\ mA$			0.3				V
			$I_C = 10\ mA$, $I_B = 0$, $I_F = 20\ mA$						0.3	
R_{in-out}	Input-to-Output Internal Resistance		$V_{in-out} = \pm 1\ kV$, See Note 3	10^{11}	10^{12}		10^{11}	10^{12}		Ω
C_{in-out}	Input-to-Output Capacitance		$V_{in-out} = 0$, $f = 1\ MHz$, See Note 3		2.5			2.5		pF

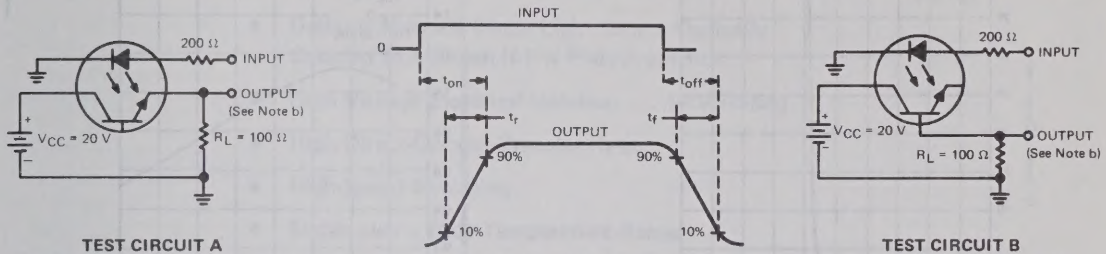
NOTE 3: These parameters are measured between all the input diode leads shorted together and all the phototransistor leads shorted together.

switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 20\ V$, $I_B = 0$, $I_{F(on)} = 5\ mA$, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1	3	µs
t_f	Fall Time			3	
t_r	Rise Time	Photodiode Operation	$V_{CC} = 20\ V$, $I_E = 0$, $I_{F(on)} = 500\ mA$, $R_L = 100\ \Omega$, See Test Circuit B of Figure 1	150	ns
t_f	Fall Time			150	

PARAMETER MEASUREMENT INFORMATION

Adjust amplitude of input pulse for:
$I_{C(on)}$ = 5 mA (Test Circuit A) or
$I_{C(on)}$ = 500 mA (Test Circuit B)


200 Ω
INPUT
OUTPUT
(See Note b)
V_{CC} = 20 V
R_L = 100 Ω
+
INPUT
0
t_{on}
t_{off}
t_r
t_f
OUTPUT
90%
90%
10%
10%
200 Ω
INPUT
V_{CC} = 20 V
OUTPUT
(See Note b)
R_L = 100 Ω
+

TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION

VOLTAGE WAVEFORMS

TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. The input waveform is supplied by a generator with the following characteristics: z_{out} = 50 Ω, $t_r \leqslant 15$ ns, duty cycle ≈ 1%. For Test Circuit A, t_w = 100 μs. For Test Circuit B, t_w = 1 μs.

b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL102
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

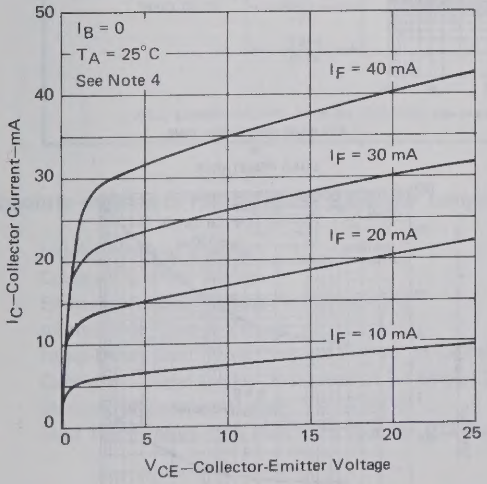


FIGURE 2

TIL103
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

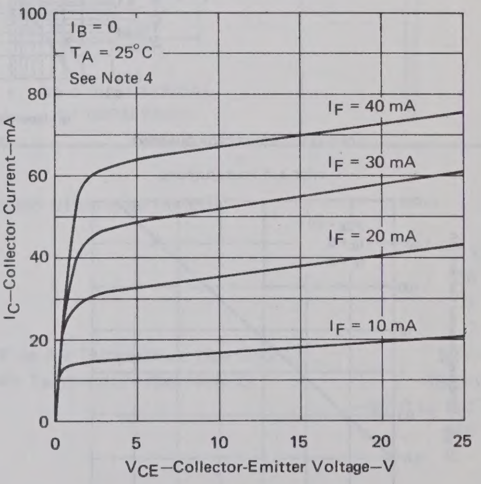


FIGURE 3

NOTE 4: This parameter was measured using pulse techniques, t_w = 100 μs, duty cycle = 1%.

TYPICAL CHARACTERISTICS

INPUT DIODE FORWARD CONDUCTION CHARACTERISTICS

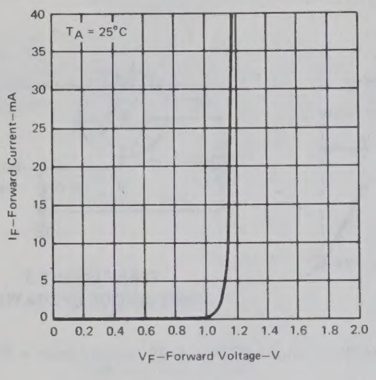
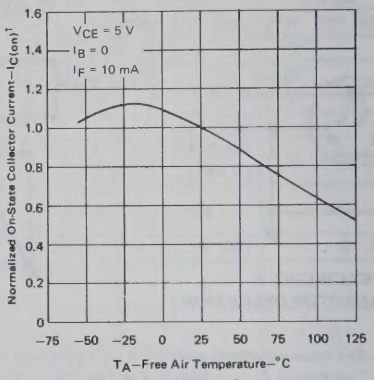


FIGURE 4

NORMALIZED ON-STATE COLLECTOR CURRENT†
vs
FREE-AIR TEMPERATURE



†Normalized to value at T_A = 25°C

FIGURE 5

PHOTOTRANSISTOR COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

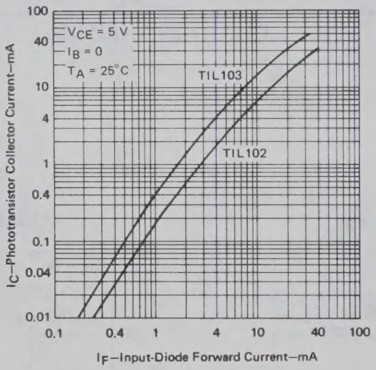


FIGURE 6

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

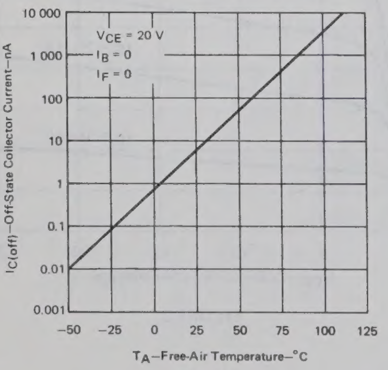


FIGURE 7

AVERAGE SWITCHING TIME
vs
LOAD RESISTANCE

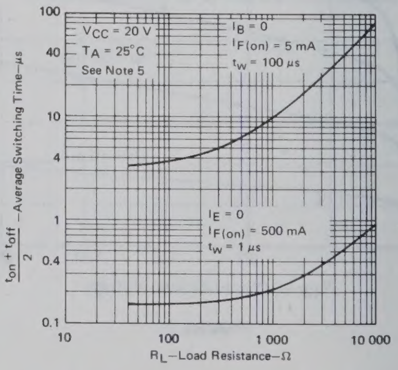


FIGURE 8

NOTE 5: These parameters were measured in Test Circuits A and B of Figure 1 with R_L varied between 40 Ω and 10 kΩ.

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TYPES TIL107, TIL108
OPTICALLY COUPLED ISOLATORS

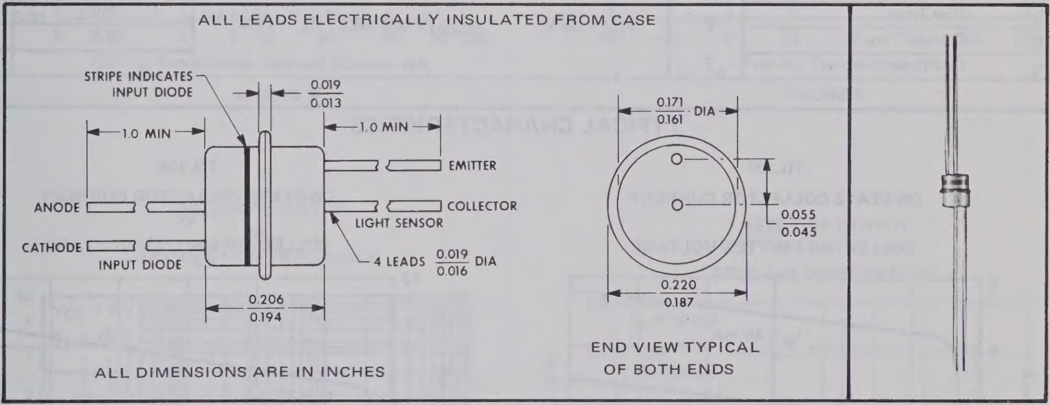
TYPES TIL107, TIL108
BULLETIN NO. DL-S 7011316, MARCH 1970

COMPATIBLE WITH STANDARD DTL AND TTL INTEGRATED CIRCUITS

- Ideal for Replacement of Relays and Pulse Transformers
- Gallium Arsenide Diode Light Source Optically Coupled to a Silicon N-P-N Phototransistor
- High-Voltage Electrical Isolation . . . 1-kV Rating
- High Direct-Current Transfer Ratio
- High-Speed Switching
- Stable over a Wide Temperature Range
- Rugged, Hermetically Sealed Package

mechanical data

Welded case with glass-to-metal hermetic seal between case and leads. Unit weight is approximately 4.5 grams.


ALL LEADS ELECTRICALLY INSULATED FROM CASE
STRIPE INDICATES INPUT DIODE
0.019
0.013
1.0 MIN
1.0 MIN
EMITTER
ANODE
COLLECTOR
LIGHT SENSOR
CATHODE
INPUT DIODE
4 LEADS 0.019/0.016 DIA
0.206
0.194
ALL DIMENSIONS ARE IN INCHES
0.171
0.161
DIA
0.055
0.045
0.220
0.187
END VIEW TYPICAL OF BOTH ENDS

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	± 1 kV
Collector-Emitter Voltage	35 V
Emitter-Collector Voltage	7 V
Input-Diode Reverse Voltage	2 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	50 mA
Continuous Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	150 mW
Storage Temperature Range	−55°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. Derate linearly to 125°C free-air temperature at the rate of 0.5 mA/°C.

2. Derate linearly to 125°C free-air temperature at the rate of 1.5 mW/°C. In these devices, a significant portion of the total dissipation is in the input diode. $P_T = V_{CE}\,I_C + V_F\,I_F$.

TYPES TIL107, TIL108
OPTICALLY COUPLED ISOLATORS

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST FIGURE	TEST CONDITIONS		TIL107			TIL108			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
$I_{C(on)}$	On-State Collector Current	A	$V_{CE} = 5$ V,	$I_F = 15$ mA	0.5	1		1.6	2		mA
			$V_{CE} = 5$ V,	$I_F = 35$ mA	1.6	4		5	7		
$I_{C(off)}$	Off-State Collector Current	B	$V_{CE} = 30$ V,	$I_F = 0$			25			25	nA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	C	$I_F = 15$ mA,	$I_C = 125\ \mu$A			0.3			0.3	V
V_F	Input-Diode Static Forward Voltage	D	$I_F = 15$ mA				1.5			1.5	V
$R_{in\text{-}out}$	Input-to-Output Internal Resistance		$V_{in\text{-}out} = \pm 1$ kV			$>10^{13}$			$>10^{13}$		Ω
$C_{in\text{-}out}$	Input-to-Output Internal Capacitance		$V_{in\text{-}out} = 100$ V, f = 50 MHz			0.4			0.4		pF

switching characteristics at 25°C free-air temperature

PARAMETER		TEST FIGURE	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_d	Delay Time	E	$V_{CC} = 35$ V, $I_{C(on)} = 500\ \mu$A, $R_L = 1$ kΩ		3.0		μs
t_r	Rise Time				5.0		μs
t_s	Storage Time				0.5		μs
t_f	Fall Time				5.0		μs

TYPICAL CHARACTERISTICS

TIL107

ON-STATE COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

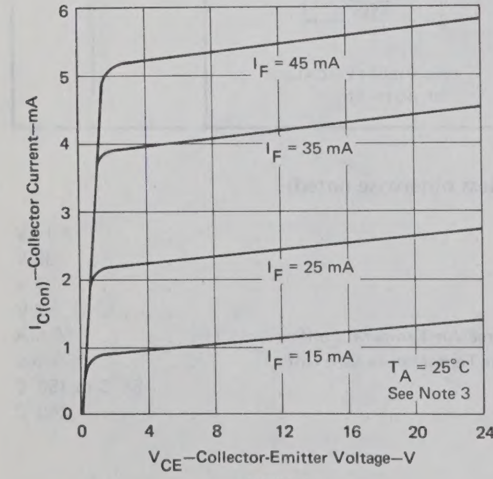


FIGURE 1

TIL108

ON-STATE COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

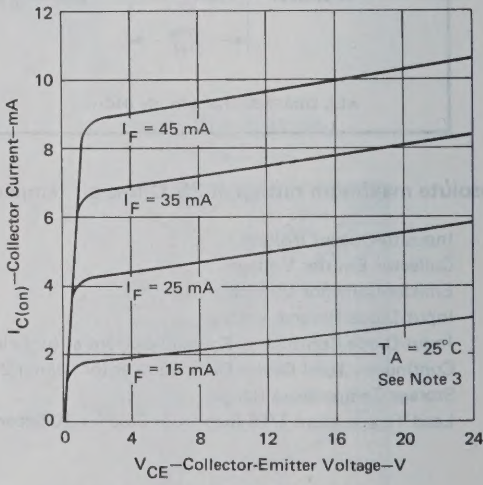


FIGURE 2

NOTE 3: This parameter must be measured using pulse techniques. $t_p = 300\ \mu$s, duty cycle $\leqslant 2\%$.

TYPICAL CHARACTERISTICS

PHOTOTRANSISTOR COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

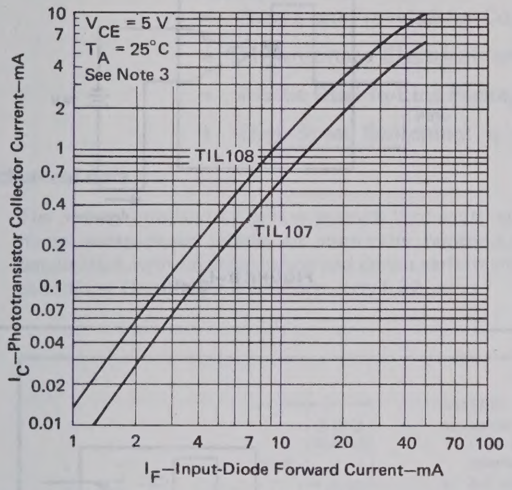


FIGURE 3

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

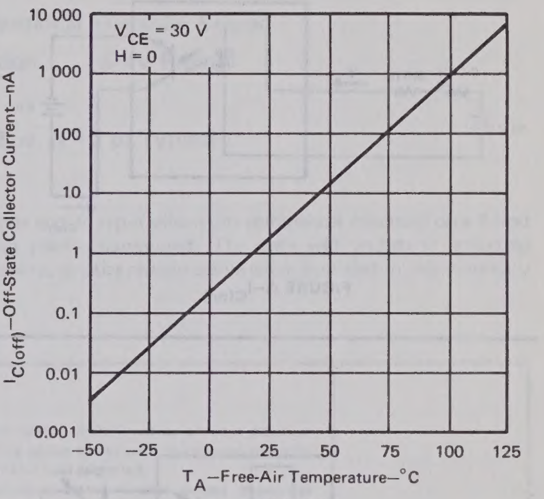


FIGURE 4

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

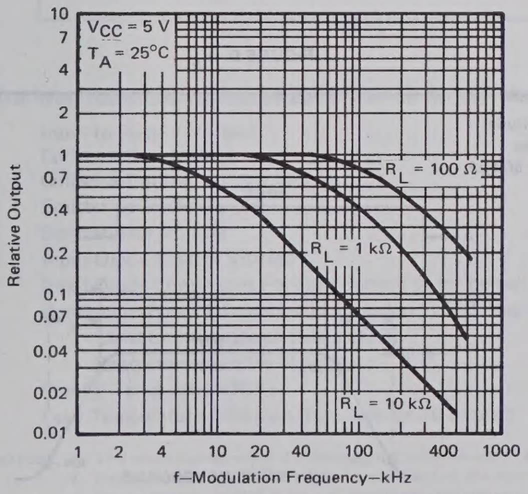


FIGURE 5

RELATIVE OUTPUT
vs
FREE-AIR TEMPERATURE

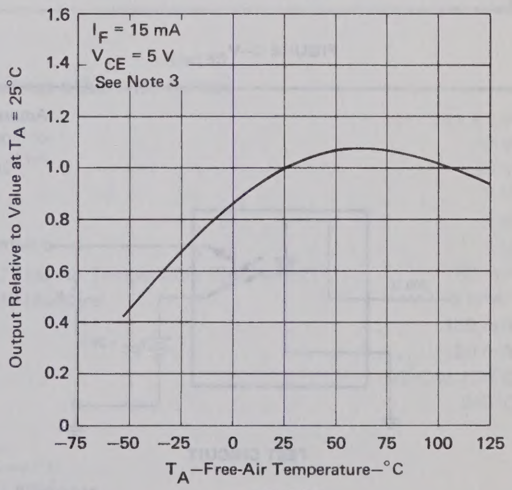


FIGURE 6

NOTE 3: This parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

PARAMETER MEASUREMENT INFORMATION

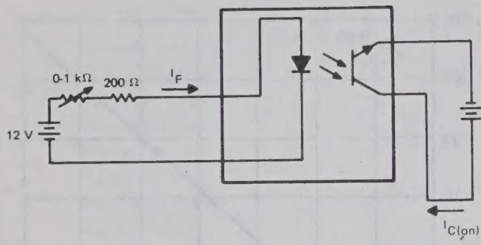

0-1 kΩ
200 Ω
I_F
12 V
5 V
I_C(on)

FIGURE A–$I_{C(on)}$

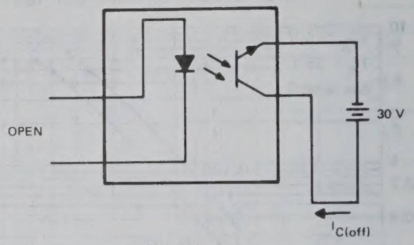

OPEN
30 V
I_C(off)

FIGURE B–$I_{C(off)}$

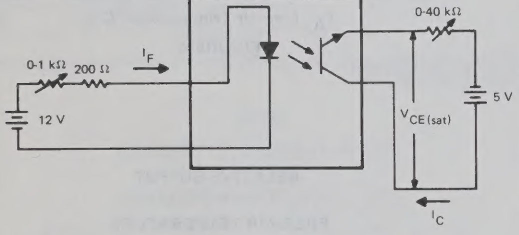

0-1 kΩ
200 Ω
I_F
12 V
0-40 kΩ
5 V
V_CE(sat)
I_C

FIGURE C–$V_{CE(sat)}$

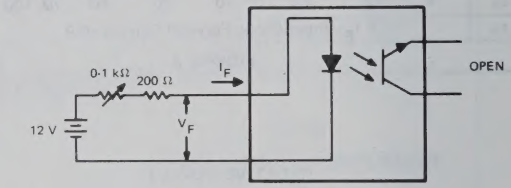
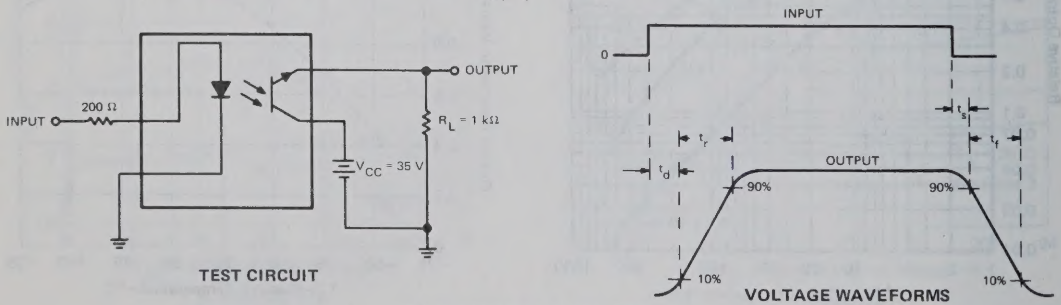

0-1 kΩ
200 Ω
I_F
12 V
V_F
OPEN

FIGURE D–V_F

Adjust amplitude
of input pulse
for $I_{C(on)} = 500\ \mu A$


OUTPUT
INPUT
200 Ω
R_L = 1 kΩ
V_CC = 35 V
INPUT
0
t_s
t_r
t_f
t_d
OUTPUT
90%
90%
10%
10%

TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE E–SWITCHING TIMES

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 100$ ns, $t_w = 50\ \mu s$, duty cycle ≈ 50%.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

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TYPE TIL111
OPTICALLY COUPLED ISOLATOR

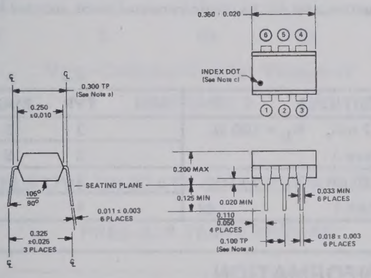
TYPE TIL111
BULLETIN NO. DL-S 7111546, SEPTEMBER 1971

COMPATABLE WITH STANDARD DTL AND TTL INTEGRATED CIRCUITS

- Gallium Arsenide Diode Light Source Optically Coupled to a Silicon N-P-N Phototransistor
- High Direct-Current Transfer Ratio
- Base Lead Provided for Conventional Transistor Biasing
- High-Voltage Electrical Isolation . . . 1.5-kV Rating
- Plastic Dual-In-Line Package
- High-Speed Switching: $t_r = 2\ \mu s$, $t_f = 2\ \mu s$ Typical

mechanical data

The package consists of a gallium arsenide light-emitting diode and an n-p-n silicon phototransistor mounted on a 6-lead frame encapsulated within an electrically nonconductive plastic compound. The case will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Unit weight is approximately 0.52 grams.



NOTES:

a. Leads are within 0.005 radius of true position (TP) at the gauge plane with maximum material condition and unit installed.

b. All dimensions are in inches unless otherwise noted.

c. Pin 1 identified by index dot.

d. Terminal connections:

1. Anode
2. Cathode } Light-emitting diode
3. No internal connection
4. Emitter
5. Collector } Phototransistor
6. Base

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1.5 kV
Collector-Base Voltage	70 V
Collector-Emitter Voltage (See Note 1)	30 V
Emitter-Collector Voltage	7 V
Emitter-Base Voltage	7 V
Input-Diode Reverse Voltage	3 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	60 mA
Continuous Power Dissipation at (or below) 25°C Free-Air Temperature:	
Light-Emitting Diode (See Note 3)	100 mW
Phototransistor (See Note 4)	150 mW
Storage Temperature Range	−55°C to 150°C
Lead Temperature 1/16 inch from case for 10 seconds	240°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 100°C free-air temperature at the rate of 0.8 mA/°C.
3. Derate linearly to 100°C free-air temperature at the rate of 1.33 mW/°C.
4. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.

electrical characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		I_C = 10 μA, I_E = 0, I_F = 0	70			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		I_C = 1 mA, I_B = 0, I_F = 0	30			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		I_E = 10 μA, I_C = 0, I_F = 0	7			V
$I_{C(on)}$	On-State Collector Current	Phototransistor Operation	V_{CE} = 0.4 V, I_B = 0, I_F = 16 mA	2	7		mA
		Photodiode Operation	V_{CB} = 0.4 V, I_E = 0, I_F = 16 mA	10	20		μA
$I_{C(off)}$	Off-State Collector Current	Phototransistor Operation	V_{CE} = 10 V, I_B = 0, I_F = 0		1	50	nA
		Photodiode Operation	V_{CB} = 10 V, I_E = 0, I_F = 0		0.1	20	nA
h_{FE}	Transistor Static Forward Current Transfer Ratio		V_{CE} = 5 V, I_C = 10 mA, I_F = 0	100	300		
V_F	Input Diode Static Forward Voltage		I_F = 16 mA		1.2	1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		I_C = 2 mA, I_B = 0, I_F = 16 mA		0.25	0.4	V
R_{in-out}	Input-to-Output Internal Resistance		V_{in-out} = ±1.5 kV, See Note 5	10^{11}			Ω
C_{in-out}	Input-to-Output Capacitance		V_{in-out} = 0, f = 1 MHz, See Note 5		1	1.3	pF

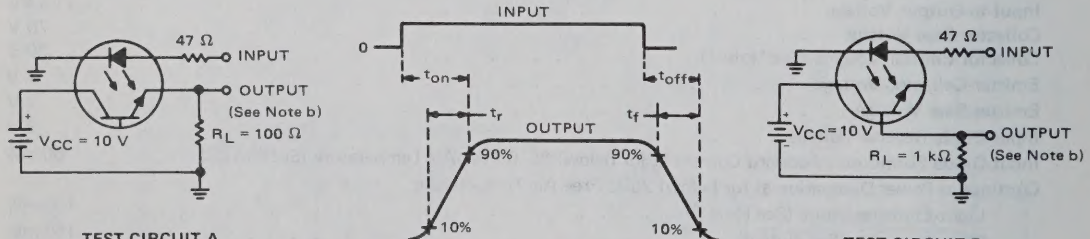
NOTE 5: These parameters are measured between both input diode leads shorted together and all the phototransistor leads shorted together.

switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	Rise Time	Phototransistor Operation	V_{CC} = 10 V, $I_{C(on)}$ = 2 mA, R_L = 100 Ω, See Test Circuit A of Figure 1		2	5	μs
t_f	Fall Time				2	5	
t_r	Rise Time	Photodiode Operation	V_{CC} = 10 V, $I_{C(on)}$ = 20 μA, R_L = 1 kΩ, See Test Circuit B of Figure 1		1		μs
t_f	Fall Time				1		

PARAMETER MEASUREMENT INFORMATION

Adjust amplitude of input pulse for:
$I_{C(on)}$ = 2 mA (Test Circuit A) or
$I_{C(on)}$ = 20 μA (Test Circuit B)



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION

VOLTAGE WAVEFORMS

TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. The input waveform is supplied by a generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leqslant$ 15 ns, duty cycle ≈ 1%, t_w = 100 μs.

b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant$ 12 ns, $R_{in} \geqslant$ 1 MΩ, $C_{in} \leqslant$ 20 pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

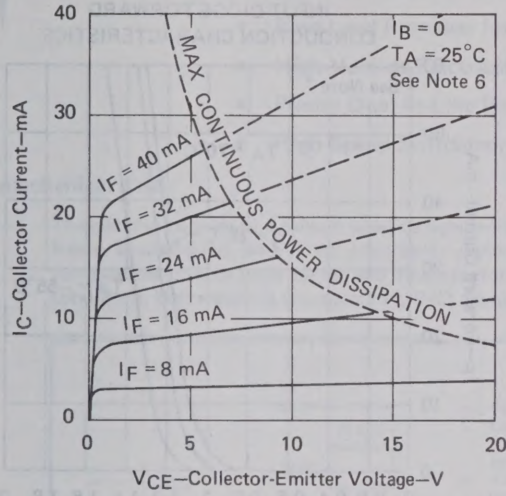


FIGURE 2

COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

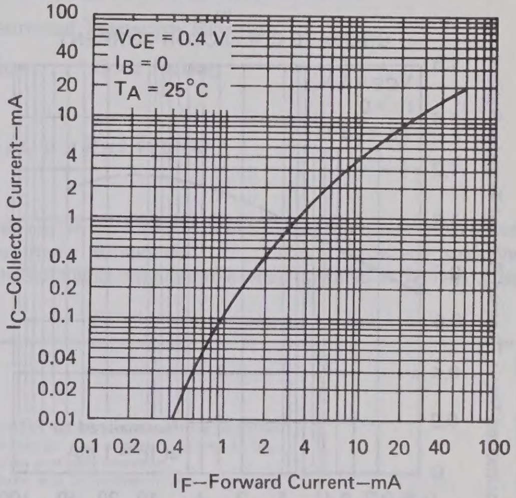


FIGURE 3

RELATIVE ON-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

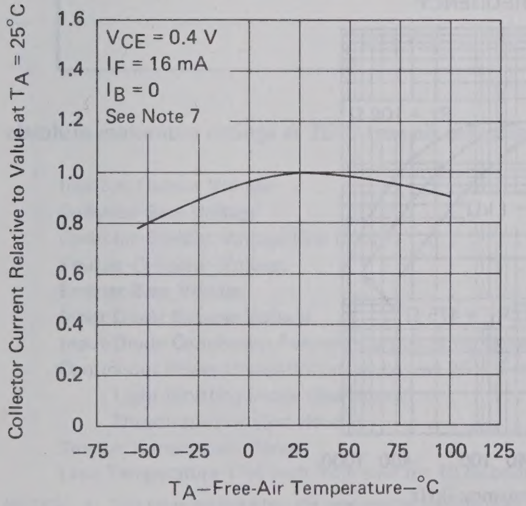


FIGURE 4

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

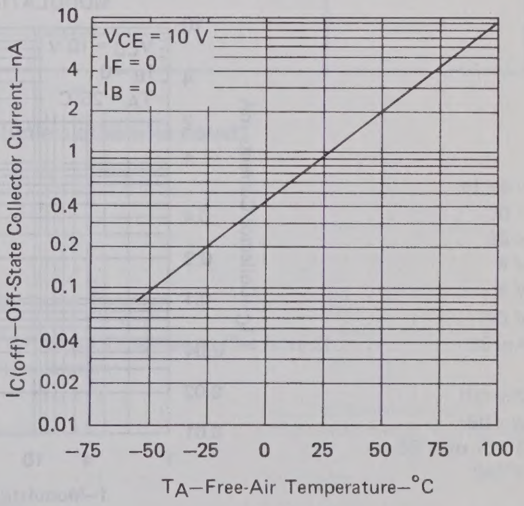


FIGURE 5

NOTES: 6. Pulse operation of input diode is required for operation beyond limits shown by dotted lines.
7. These parameters were measured using pulse techniques $t_w = 1$ ms, duty cycle ≤ 2%.

TYPE TIL111
OPTICALLY COUPLED ISOLATOR

TYPICAL CHARACTERISTICS

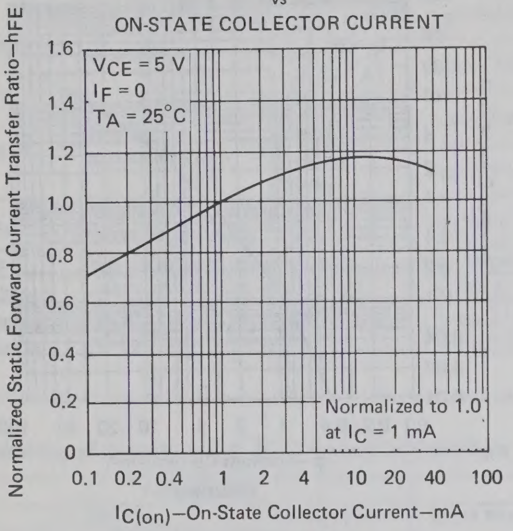

NORMALIZED TRANSISTOR STATIC FORWARD CURRENT TRANSFER RATIO vs ON-STATE COLLECTOR CURRENT

FIGURE 6

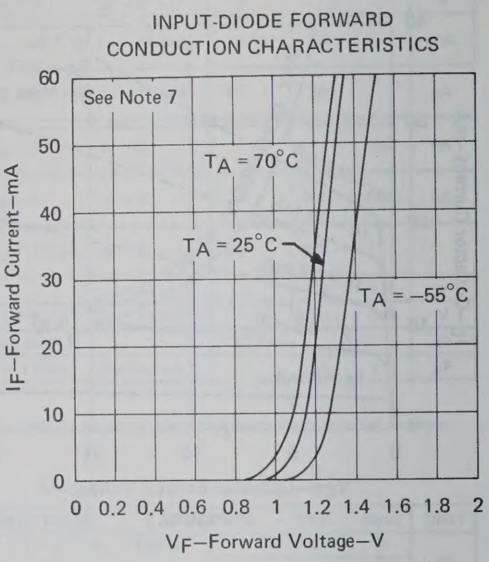

INPUT-DIODE FORWARD CONDUCTION CHARACTERISTICS

FIGURE 7

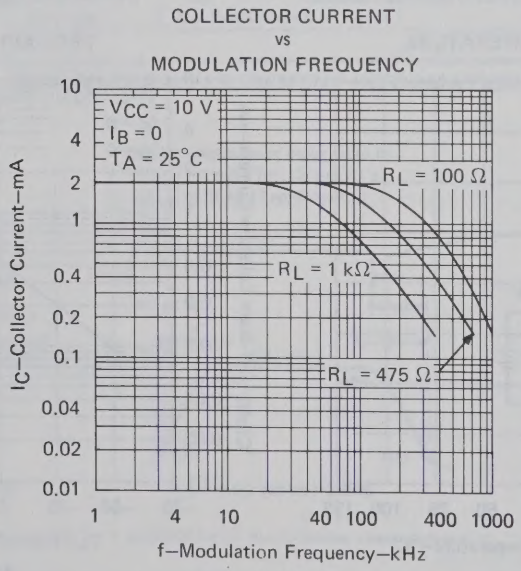

COLLECTOR CURRENT vs MODULATION FREQUENCY

FIGURE 8

NOTE 7: These parameters were measured using pulse techniques $t_w = 1$ ms, duty cycle ≤ 2%.

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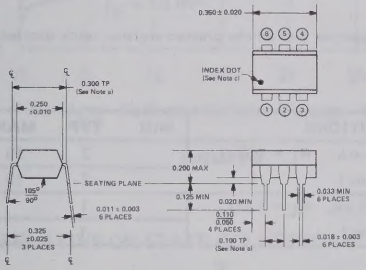
TYPE TIL112
OPTICALLY COUPLED ISOLATOR

TYPE TIL112
BULLETIN NO. DL-S 7111547, SEPTEMBER 1971

- Gallium Arsenide Diode Light Source Optically Coupled to a Silicon N-P-N Phototransistor
- High Direct-Current Transfer Ratio
- Base Lead Provided for Conventional Transistor Biasing
- High-Voltage Electrical Isolation . . . 1.5-kV Rating
- Plastic Dual-In-Line Package
- High-Speed Switching: $t_r = 2\ \mu s$, $t_f = 2\ \mu s$ Typical

mechanical data

The package consists of a gallium arsenide light-emitting diode and an n-p-n silicon phototransistor mounted on a 6-lead frame encapsulated within an electrically nonconductive plastic compound. The case will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Unit weight is approximately 0.52 grams.



NOTES:

a. Leads are within 0.005 radius of true position (TP) at the gauge plane with maximum material condition and unit installed.

b. All dimensions are in inches unless otherwise noted.

c. Pin 1 identified by index dot.

d. Terminal connection:
   1. Anode
   2. Cathode } Light-emitting diode
   3. No internal connection
   4. Emitter
   5. Collector } Phototransistor
   6. Base

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1.5 kV
Collector-Base Voltage	30 V
Collector-Emitter Voltage (See Note 1)	20 V
Emitter-Collector Voltage	4 V
Emitter-Base Voltage	4 V
Input-Diode Reverse Voltage	3 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	60 mA
Continuous Power Dissipation at (or below) 25°C Free-Air Temperature:	
Light-Emitting Diode (See Note 3)	100 mW
Phototransistor (See Note 4)	150 mW
Storage Temperature Range	−55°C to 150°C
Lead Temperature 1/16 inch from case for 10 seconds	240°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 100°C free-air temperature at the rate of 0.8 mA/°C.
3. Derate linearly to 100°C free-air temperature at the rate of 1.33 mW/°C.
4. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.

electrical characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 10\ \mu A$, $I_E = 0$, $I_F = 0$	30			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 1$ mA, $I_B = 0$, $I_F = 0$	20			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 10\ \mu A$, $I_C = 0$, $I_F = 0$	4			V
$I_{C(on)}$	On-State Collector Current	Phototransistor Operation	$V_{CE} = 5$ V, $I_B = 0$, $I_F = 10$ mA	0.2	2		mA
		Photodiode Operation	$V_{CB} = 5$ V, $I_E = 0$, $I_F = 10$ mA	2	10		µA
$I_{C(off)}$	Off-State Collector Current	Phototransistor Operation	$V_{CE} = 5$ V, $I_B = 0$, $I_F = 0$		1	100	nA
		Photodiode Operation	$V_{CB} = 5$ V, $I_E = 0$, $I_F = 0$		0.1	50	nA
h_{FE}	Transistor Static Forward Current Transfer Ratio		$V_{CE} = 5$ V, $I_C = 10$ mA, $I_F = 0$	50	200		
V_F	Input Diode Static Forward Voltage		$I_F = 10$ mA		1.2	1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 2$ mA, $I_B = 0$, $I_F = 50$ mA			0.5	V
$R_{in\text{-}out}$	Input-to-Output Internal Resistance		$V_{in\text{-}out} = \pm 1.5$ kV, See Note 5	10^{11}			Ω
$C_{in\text{-}out}$	Input-to-Output Capacitance		$V_{in\text{-}out} = 0$, f = 1 MHz, See Note 5		1	2	pF

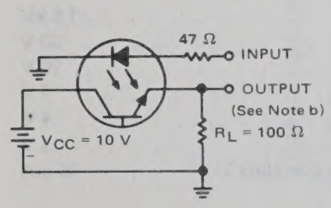
NOTE 5: These parameters are measured between both input diode leads shorted together and all the phototransistor leads shorted together.

switching characteristics at 25°C free-air temperature

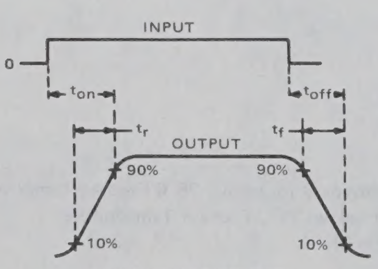
PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 10$ V, $I_{C(on)} = 2$ mA, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1		2	15	µs
t_f	Fall Time				2	15	
t_r	Rise Time	Photodiode Operation	$V_{CC} = 10$ V, $I_{C(on)} = 20\ \mu A$, $R_L = 1$ kΩ, See Test Circuit B of Figure 1		1		µs
t_f	Fall Time				1		

PARAMETER MEASUREMENT INFORMATION

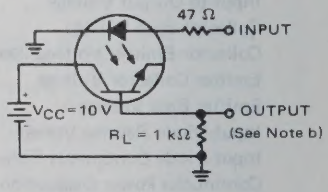
Adjust amplitude of input pulse for:
$I_{C(on)} = 2$ mA (Test Circuit A) or
$I_{C(on)} = 20\ \mu A$ (Test Circuit B)



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION



VOLTAGE WAVEFORMS



TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 15$ ns, duty cycle ≈ 1%, $t_w = 100\ \mu s$.
b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

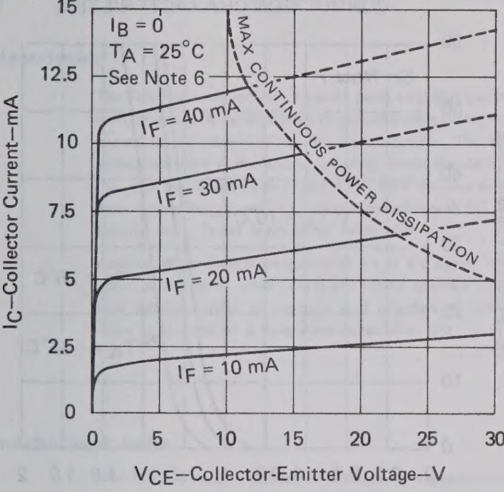


FIGURE 2

COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

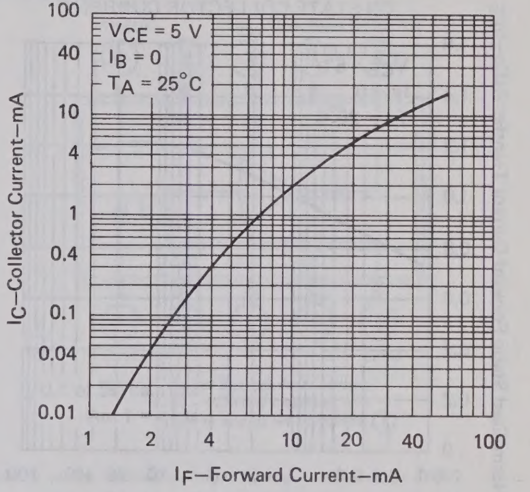


FIGURE 3

RELATIVE ON-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

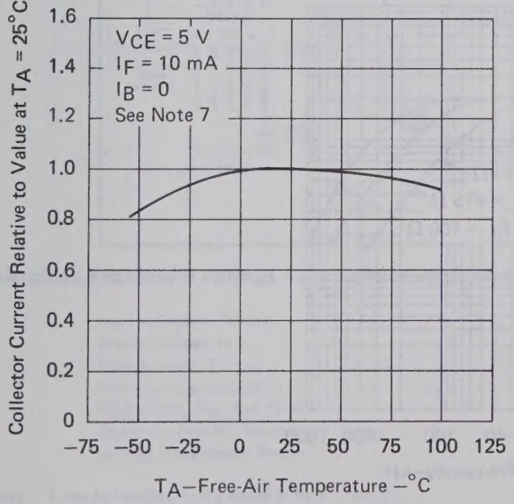


FIGURE 4

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

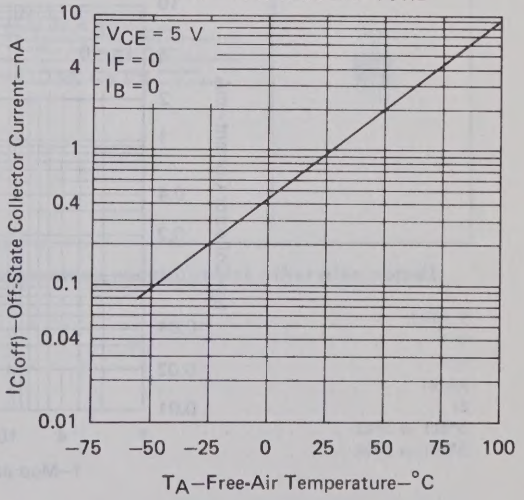


FIGURE 5

NOTES: 6. Pulse operation of input diode is required for operation beyond limits shown by dotted line.
7. These parameters were measured using pulse techniques $t_w = 1$ ms, duty cycle $\leqslant 2\%$.

TYPICAL CHARACTERISTICS

NORMALIZED TRANSISTOR STATIC FORWARD CURRENT TRANSFER RATIO
vs
ON-STATE COLLECTOR CURRENT

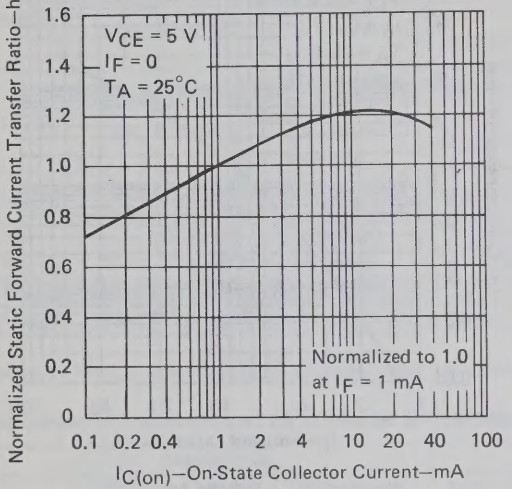


FIGURE 6

INPUT-DIODE FORWARD CONDUCTION CHARACTERISTICS

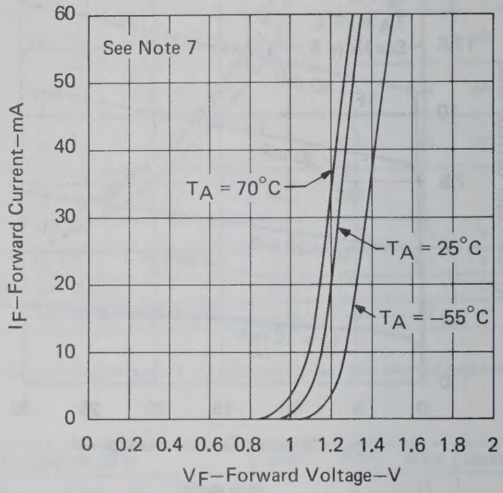


FIGURE 7

COLLECTOR CURRENT
vs
MODULATION FREQUENCY

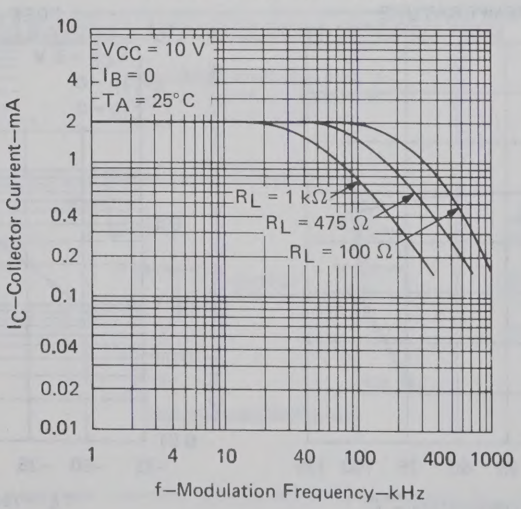


FIGURE 8

NOTE 7: These parameters were measured using pulse techniques t_w = 1 ms, duty cycle ≤ 2%.

7

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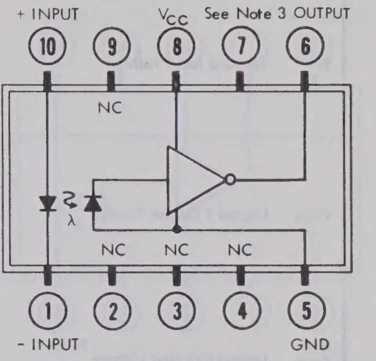
TYPE TIXL104
OPTOELECTRONIC PULSE AMPLIFIER

AN OPTICALLY COUPLED INTEGRATED CIRCUIT



NOTES: 1. Forward input polarity is indicated.
2. NC — no internal connection.
3. Make no external connection to pin ⑦

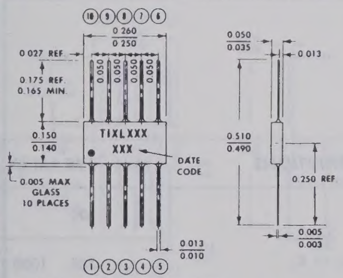
description

The TIXL104 is an optically coupled pulse amplifier consisting of a gallium arsenide light-emitting diode optically coupled to an integrated silicon photodetector feedback amplifier. The high input-output isolation of the optical coupling allows the device to function as a broad-band pulse transformer with response extending to zero frequency, as well as being compatible with RTL integrated circuits (e.g., Texas Instruments Series 51).

Applications include transmission of a-c or d-c signals across computer interfaces or other subsystems where spurious currents prevent interconnection of grounds, and rejection of common-mode noise at the end of a long data-transmission line.

mechanical data

The TIXL104 pulse amplifier is mounted in a glass-to-metal hermetically sealed, welded package. Package outline meets JEDEC TO-89. Leads are gold-plated F-15‡ glass-sealing alloy. Approximate weight is 0.1 gram. All external surfaces are metallic and are insulated from leads and circuit.



Falls within TO-89 dimensions

NOTES: a. All dimensions in inches
b. All decimals ±0.005 except as noted.
c. Lead spacing tolerance is ±0.015 at extremities and ±0.005 at package, nonaccumulative.
d. Lead centerlines are located within ±0.005 of their true positions relative to body centerlines.
e. Symbolization denotes orientation of package.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Input-to-Output Voltage	±100 V
Supply Voltage V_{CC}	7 V
Reverse Input Voltage	2 V
Forward Input Current	15 mA
DC Fan-Out, N_{DC} (See Note 1)	15
Operating Free-Air Temperature Range	−55°C to 125°C
Storage Temperature Range	−55°C to 125°C

NOTE: 1. One d-c load (N_{DC} = 1) is defined by figure A, page 2.

‡F-15 is the ASTM designation for an iron-nickel-cobalt alloy containing nominally 53% iron, 29% nickel, and 17% cobalt.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TYPE TIXL104
OPTOELECTRONIC PULSE AMPLIFIER

electrical characteristics at $V_{CC} = 6$ V

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_F	Forward Input Voltage	$I_{in} = 10$ mA	$T_A = 0$°C		1.3	1.4	V
			$T_A = 25$°C		1.2		
			$T_A = 70$°C		1.1		
$V_{out(1)}$	Logical 1 Output Voltage	$I_{in} = 0.5$ mA, $N_{DC} = 4$, See Note 1	$T_A = 0$°C	2.5	4.0		V
			$T_A = 25$°C	2.5	4.1		
			$T_A = 70$°C	2.5	4.3		
$V_{out(0)}$	Logical 0 Output Voltage	$I_{in} = 10$ mA, $N_{DC} = 4$, See Note 1	$T_A = 0$°C			0.5	V
			$T_A = 25$°C			0.5	
			$T_A = 70$°C			0.5	
	Amplifier Power Dissipation (See Note 2)	$I_{in} = 0$, $N_{DC} = 0$,	$T_A = 25$°C		50	75	mW

switching characteristics at $V_{CC} = 6$ V, $T_A = 25$°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	Rise Time	$N_{DC} = 0$, See Note 3		400		ns
t_d	Delay Time			300	1000	
t_s	Storage Time			500	1500	
t_f	Fall Time			100		

NOTES: 1. One d-c load ($N_{DC} = 1$) is defined by figure A:

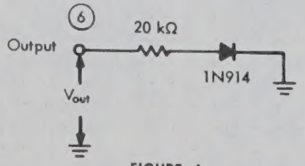


FIGURE A

2. This does not include the input power to the diode.

3. The input pulse has the following characteristics: $t_p = 5\ \mu s$, $t_r \leq 25$ ns, $t_f \leq 25$ ns, $f = 40$ kHz, amplitude $= 10$ mA.

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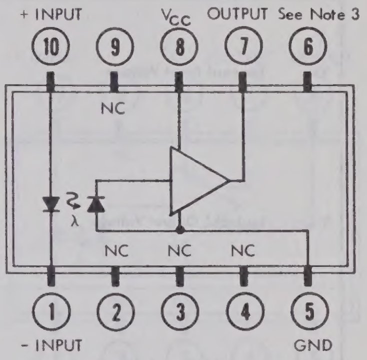
TYPE TIXL105
OPTOELECTRONIC PULSE AMPLIFIER

AN OPTICALLY COUPLED INTEGRATED CIRCUIT

description

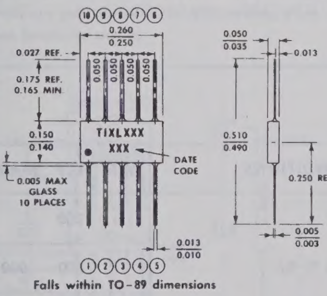
The TIXL105 is an optically coupled pulse amplifier consisting of a gallium arsenide light-emitting diode optically coupled to an integrated silicon photodetector feedback amplifier. The high input-output isolation of the optical coupling allows the device to function as a broad-band pulse transformer with response extending to zero frequency, as well as being compatible with DTL and TTL integrated circuits (e.g., Texas Instruments Series 53 and 54). Applications include transmission of a-c or d-c signals across computer interfaces or other subsystems where spurious currents prevent interconnection of grounds, and rejection of common-mode noise at the end of a long data-transmission line.



NOTES: 1. Forward input polarity is indicated.
2. NC — no internal connection.
3. Make no external connection to pin ⑥.

mechanical data

The TIXL105 pulse amplifier is mounted in a glass-to-metal hermetically sealed, welded package. Package outline meets JEDEC TO-89. Leads are gold-plated F-15‡ glass-sealing alloy. Approximate weight is 0.1 gram. All external surfaces are metallic and are insulated from leads and circuit.



Falls within TO-89 dimensions

NOTES: a. All dimensions in inches
b. All decimals ±0.005 except as noted.
c. Lead spacing tolerance is ±0.015 at extremities and ±0.005 at package, nonaccumulative.
d. Lead centerlines are located within ±0.005 of their true positions relative to body centerlines.
e. Symbolization denotes orientation of package.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Input-to-Output Voltage	±100 V
Supply Voltage V_{CC}	7 V
Reverse Input Voltage	2 V
Forward Input Current	15 mA
DC Fan-Out, N_{DC} (See Note 1)	15
Operating Free-Air Temperature Range	−55°C to 125°C
Storage Temperature Range	−55°C to 125°C

NOTE: 1. One d-c load (N_{DC} = 1) is defined by figure A, page 2.

‡F-15 is the ASTM designation for an iron-nickel-cobalt alloy containing nominally 53% iron, 29% nickel, and 17% cobalt.

PRELIMINARY DATA SHEET: Supplementary data may be published at a later date.

TYPE TIXL105
OPTOELECTRONIC PULSE AMPLIFIER

electrical characteristics at $V_{CC} = 6$ V

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_F	Forward Input Voltage	$I_{in} = 10$ mA	$T_A = 0°C$		1.3	1.4	V
			$T_A = 25°C$		1.2		
			$T_A = 70°C$		1.1		
$V_{out(1)}$	Logical 1 Output Voltage	$I_{in} = 10$ mA, $N_{DC} = 7$, See Note 1	$T_A = 0°C$	5			V
			$T_A = 25°C$	5			
			$T_A = 70°C$	5			
$V_{out(0)}$	Logical 0 Output Voltage	$I_{in} = 0.5$ mA, $N_{DC} = 7$, See Note 1	$T_A = 0°C$			0.5	V
			$T_A = 25°C$			0.5	
			$T_A = 70°C$			0.5	
	Amplifier Power Dissipation (See Note 2)	$I_{in} = 0$, $N_{DC} = 0$,	$T_A = 25°C$		50	75	mW

switching characteristics at $V_{CC} = 6$ V, $T_A = 25°C$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	Rise Time	$N_{DC} = 0$, See Note 3		200		ns
t_d	Delay Time			600	1000	
t_s	Storage Time			500	1500	
t_f	Fall Time			100		

NOTES: 1. One d-c load ($N_{DC} = 1$) is defined by figure A:

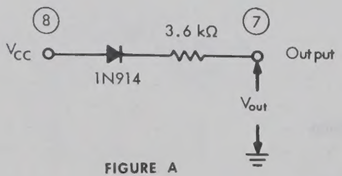


FIGURE A

2. This does not include the input power to the diode.

3. The input pulse has the following characteristics: $t_p = 5\ \mu s$, $t_r \leq 25$ ns, $t_f \leq 25$ ns, f = 40 kHz, amplitude = 10 mA.

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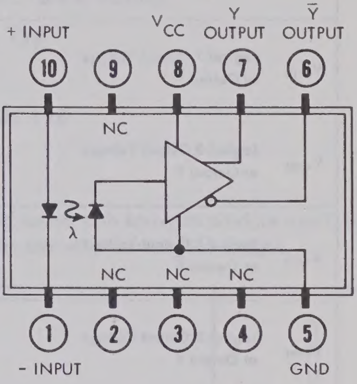
TYPE TIXL106
OPTOELECTRONIC PULSE AMPLIFIER

TYPE TIXL106
BULLETIN NO. DL-S 6810808, OCTOBER 1968

AN OPTICALLY COUPLED INTEGRATED CIRCUIT

description

The TIXL106 is an optically coupled pulse amplifier consisting of a gallium arsenide light-emitting diode optically coupled to an integrated silicon photodetector feedback amplifier. The high input-output isolation of the optical coupling allows the device to function as a broad-band pulse transformer with response extending to zero frequency, as well as being compatible with RTL, TTL, and DTL integrated circuits. Applications include transmission of a-c or d-c signals across computer interfaces or other subsystems where spurious currents prevent interconnection of grounds, and rejection of common-mode noise at the end of a long data-transmission line.

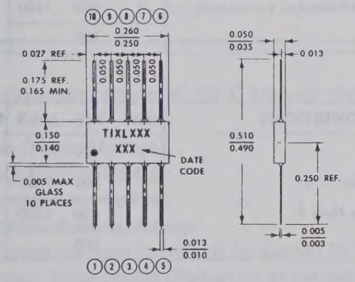


+ INPUT
VCC
Y OUTPUT
$\bar{Y}$ OUTPUT
10
9
8
7
6
NC
λ
NC
NC
NC
1
2
3
4
5
- INPUT
GND

NOTES: 1. Forward input polarity is indicated.
2. NC — no internal connection.

mechanical data

The TIXL106 pulse amplifier is mounted in a glass-to-metal hermetically sealed, welded package. Package outline meets JEDEC TO-89. Leads are gold-plated F-15‡ glass-sealing alloy. Approximate weight is 0.1 gram. All external surfaces are metallic and are insulated from leads and circuit.



10 9 8 7 6
0.260
0.250
0.027 REF.
0.050
0.050
0.050
0.050
0.175 REF.
0.165 MIN.
0.150
0.140
TIXLXXX
XXX
DATE CODE
0.005 MAX GLASS 10 PLACES
0.050
0.035
0.013
0.510
0.490
0.250 REF.
0.005
0.003
0.013
0.010
1 2 3 4 5

NOTES: a. All dimensions in inches
b. All decimals ±0.005 except as noted.
c. Lead spacing tolerance is ±0.015 at extremities and ±0.005 at package, nonaccumulative.
d. Lead centerlines are located within ±0.005 of their true positions relative to body centerlines.
e. Symbolization denotes orientation of package.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Input-to-Output Voltage	±100 V
Supply Voltage V_{CC}	7 V
Reverse Input Voltage	2 V
Forward Input Current	15 mA
DC Fan-Out, N_{DC} (See Note 1)	15
Operating Free-Air Temperature Range	−55°C to 125°C
Storage Temperature Range	−55°C to 125°C

NOTE: 1. One d-c load (N_{DC} = 1) is defined by figure A, page 2.

‡F-15 is the ASTM designation for an iron-nickel-cobalt alloy containing nominally 53% iron, 29% nickel, and 17% cobalt.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TYPE TIXL106
OPTOELECTRONIC PULSE AMPLIFIER

electrical characteristics at $V_{CC} = 6$ V

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_F	Forward Input Voltage	$I_{in} = 10$ mA	$T_A = 0°C$		1.3	1.4	V
			$T_A = 25°C$		1.2		
			$T_A = 70°C$		1.1		
$V_{out(1)}$	Logical 1 Output Voltage at Output Y	$I_{in} = 10$ mA, $N_{DC} = 7$, See Note 1	$T_A = 0°C$	5			V
			$T_A = 25°C$	5			
			$T_A = 70°C$	5			
$V_{out(0)}$	Logical 0 Output Voltage at Output Y	$I_{in} = 0.5$ mA, $N_{DC} = 7$, See Note 1	$T_A = 0°C$			0.5	V
			$T_A = 25°C$			0.5	
			$T_A = 70°C$			0.5	
$V_{out(1)}$	Logical 1 Output Voltage at Output $\overline{Y}$	$I_{in} = 0.5$ mA, $N_{DC} = 4$, See Note 1	$T_A = 0°C$	2.5	4.0		V
			$T_A = 25°C$	2.5	4.1		
			$T_A = 70°C$	2.5	4.3		
$V_{out(0)}$	Logical 0 Output Voltage at Output $\overline{Y}$	$I_{in} = 10$ mA, $N_{DC} = 4$, See Note 1	$T_A = 0°C$			0.5	V
			$T_A = 25°C$			0.5	
			$T_A = 70°C$			0.5	
	Amplifier Power Dissipation (See Note 2)	$I_{in} = 0$, $N_{DC} = 0$,	$T_A = 25°C$		50	75	mW

switching characteristics at Y output, $V_{CC} = 6$ V, $T_A = 25°C$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	Rise Time	$N_{DC} = 0$, See Note 3		200		ns
t_d	Delay Time			600	1000	
t_s	Storage Time			500	1500	
t_f	Fall Time			100		

switching characteristics at $\overline{Y}$ output, $V_{CC} = 6$ V, $T_A = 25°C$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	Rise Time	$N_{DC} = 0$, See Note 3		400		ns
t_d	Delay Time			300	1000	
t_s	Storage Time			500	1500	
t_f	Fall Time			100		

NOTES: 1. One d-c load ($N_{DC} = 1$) is defined by figure A:

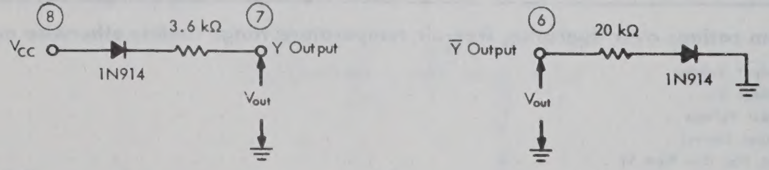


FIGURE A

2. This does not include the input power to the diode.

3. The input pulse has the following characteristics: $t_p = 5\ \mu s$, $t_r \leq 25$ ns, $t_f \leq 25$ ns, f = 40 kHz, amplitude = 10 mA.

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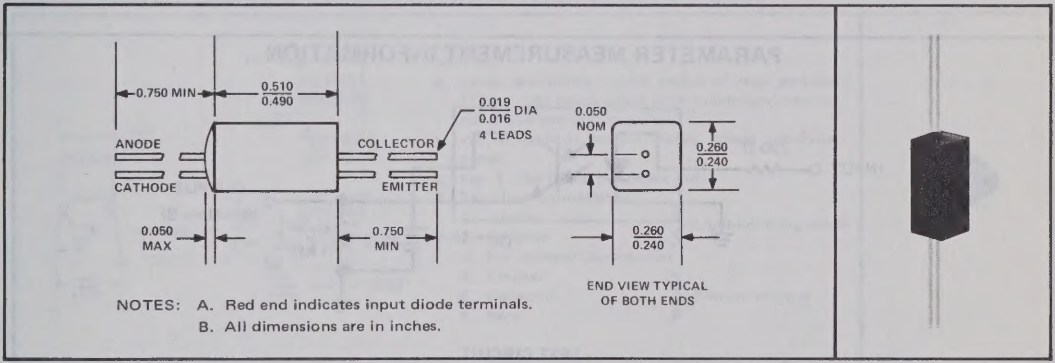
TYPE TIXL109
OPTICALLY COUPLED ISOLATOR

GALLIUM ARSENIDE DIODE LIGHT SOURCE OPTICALLY COUPLED TO A SILICON N-P-N PHOTOTRANSISTOR

- Ideal for Electrical Isolation and Relay Replacement in High-Vibration Applications
- Provides High-Voltage Electrical Isolation: 5-kV Rating
- Output Current: 250 μA Min, 1500 μA Typ
- Stable over a Wide Temperature Range
- High-Speed Switching: $t_r = 5\ \mu s$, $t_f = 5\ \mu s$ Typ

mechanical data

These devices are mounted in a precast epoxy shell which is filled and sealed with epoxy to produce a solid assembly. The case will withstand soldering temperature without deformation. The assembly is insensitive to light.



NOTES: A. Red end indicates input diode terminals.
B. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±5 kV
Collector-Emitter Voltage	15 V
Emitter-Collector Voltage	5 V
Input Diode Reverse Voltage	2 V
Input Diode Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	50 mA
Continuous Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	150 mW
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.
2. Derate linearly to 80°C free-air temperature the the rate of 2.73 mW/°C. In these devices, a significant portion of the dissipation is in the input diode. $P_T = V_{CE} I_C + V_F I_F$.

TENTATIVE DATA SHEET
This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

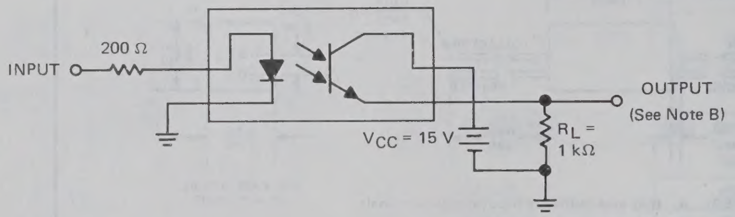
PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$,	$I_F = 0$		15			V
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 5\ V$,	$I_F = 35\ mA$		250	1500		μA
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 5\ V$,	$I_F = 0$				500	nA
		$V_{CE} = 5\ V$,	$I_F = 0$,	$T_A = 80°C$		10		μA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_F = 35\ mA$,	$I_C = 250\ \mu A$			0.2		V
V_F	Input Diode Static Forward Voltage	$I_F = 35\ mA$				1.2	1.9	V
$R_{in\text{-}out}$	Input-to-Output Internal Resistance	$V_{in\text{-}out} = \pm 5\ kV$,	See Note 3			$> 10^{13}$		Ω

NOTE 3: This parameter is measured between both input diode leads shorted together and both phototransistor leads shorted together.

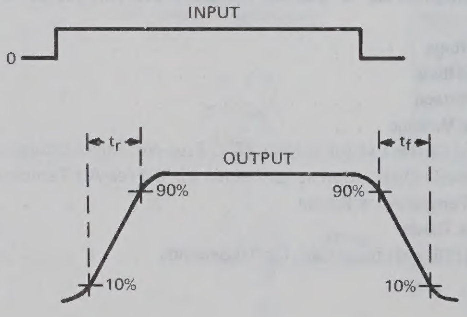
switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS		TYP	UNIT
t_r	Rise Time	$V_{CC} = 15\ V$,	$I_{C(on)} = 250\ \mu A$,	5	μs
t_f	Fall Time	$R_L = 1\ k\Omega$,	See Figure 1	5	μs

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



Adjust amplitude
of input pulse
for $I_{C(on)}$ = 250 μA

VOLTAGE WAVEFORMS

FIGURE 1–SWITCHING TIMES

NOTES: A. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 100$ ns, $t_w = 50\ \mu s$, duty cycle ≈ 50%.

B. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

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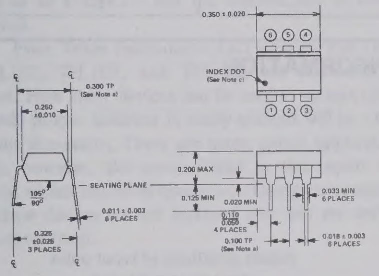
TYPE TIXL113
OPTICALLY COUPLED ISOLATOR

- Gallium Arsenide Diode Light Source Optically Coupled to a Silicon N-P-N Darlington-Connected Phototransistor
- High Direct-Current Transfer Ratio: 100% Minimum from 2.5 to 10 mA
- Base Lead Provided for Conventional Transistor Biasing
- High-Voltage Electrical Isolation . . . 1500-Volt Rating
- Plastic Dual-In-Line Package
- Typical Applications Include Remote Terminal Isolation, SCR and Triac Triggers, Mechanical Relays, and Pulse Transformers

mechanical data

The package consists of a gallium arsenide light-emitting diode and an n-p-n silicon darlington-connected phototransistor mounted on a 6-lead frame encapsulated within an electrically nonconductive plastic compound. The case will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Unit weight is approximately 0.52 grams.



NOTES:
a. Leads are within 0.005 radius of true position (TP) at the gauge plane with maximum material condition and unit installed.
b. All dimensions are in inches unless otherwise noted.
c. Pin 1 identified by index dot.
d. Terminal connections:
   1. Anode } Light-emitting diode
   2. Cathode
   3. No internal connection
   4. Emitter } Phototransistor
   5. Collector
   6. Base

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1.5 kV
Collector-Base Voltage	30 V
Collector-Emitter Voltage (See Note 1)	30 V
Emitter-Collector Voltage	7 V
Emitter-Base Voltage	7 V
Input-Diode Reverse Voltage	3 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	60 mA
Continuous Power Dissipation at (or below) 25°C Free-Air Temperature:	
Light-Emitting Diode (See Note 3)	100 mW
Phototransistor (See Note 4)	150 mW
Storage Temperature Range	−55°C to 150°C
Lead Temperature 1/16 inch from case for 10 seconds	240°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 100°C free-air temperature at the rate of 0.8 mA/°C.
3. Derate linearly to 100°C free-air temperature at the rate of 1.33 mW/°C.
4. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TYPE TIXL113
OPTICALLY COUPLED ISOLATOR

electrical characteristics at 25°C free-air temperature

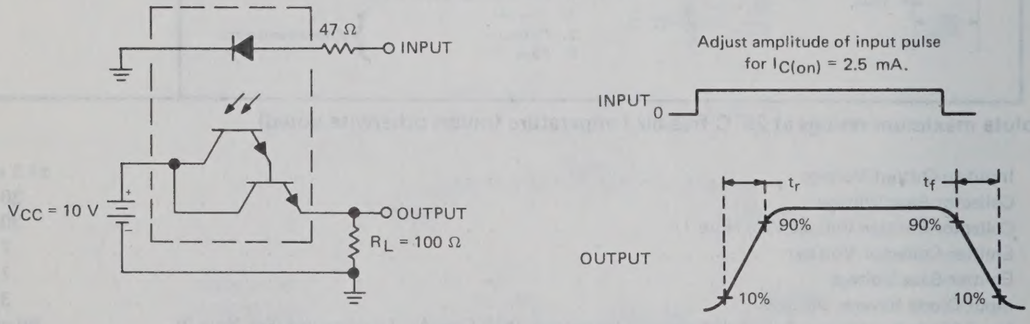
PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$,	$I_E = 0$,	$I_F = 0$	30			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 1$ mA,	$I_B = 0$,	$I_F = 0$	30			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$,	$I_C = 0$,	$I_F = 0$	7			V
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 1$ V,	$I_B = 0$,	$I_F = 2.5$ mA	2.5	6		mA
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 10$ V,	$I_B = 0$,	$I_F = 0$			100	nA
h_{FE}	Transistor Static Forward Current Transfer Ratio	$V_{CE} = 1$ V,	$I_C = 10$ mA,	$I_F = 0$		15 000		
V_F	Input Diode Static Forward Voltage	$I_F = 10$ mA					1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 10$ mA,	$I_B = 0$,	$I_F = 10$ mA			1	V
$R_{in\text{-}out}$	Input-to-Output Internal Resistance	$V_{in\text{-}out} = \pm 1.5$ W,	See Note 5		10^{11}			Ω
$C_{in\text{-}out}$	Input-to-Output Capacitance	$V_{in\text{-}out} = 0$,	f = 1 MHz,	See Note 5		1	1.3	pF

NOTE 5: These parameters are measured between both input diode leads shorted together and all the phototransistor leads shorted together.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 10$ V, $I_{C(on)} = 2.5$ mA, $R_L = 100\ \Omega$, See Figure 1	50	μs
t_f	Fall Time		50	μs

PARAMETER MEASUREMENT INFORMATION



Adjust amplitude of input pulse for $I_{C(on)} = 2.5$ mA.

TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 15$ ns, duty cycle ≈ 1%, $t_w = 100\ \mu s$.

b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

FIGURE 1—SWITCHING TIMES

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OPTICALLY COUPLED ISOLATORS IN CIRCUITS

Howard T. Russell

There are many situations in which information must be transmitted between switching circuits electrically isolated from each other. This isolation has been commonly provided by relays, isolation transformers, and line drivers and receivers. There is, however, another device which can be used quite effectively to solve these problems. This device is the optically coupled isolator, also called OCI. The need for the OCI is most prominent in areas where high voltage and noise isolation, as well as small size, are considered important. By coupling two systems together with the transmission of light energy (photons), the necessity for a common ground is eliminated – the main purpose of the OCI – and the systems can be effectively isolated.

Four Texas Instruments OCI devices, the TIXL102, TIXL103, TIL107, and TIL108, are discussed in this report. How these devices can be used in various circuits to provide proper isolation in many systems will be a key part of this discussion. There are many circuit applications for OCIs; however, the ones offered in this report are just several which can be of special use. Complete specifications for these devices are not included here but are available in data-sheet form.

DESCRIPTION OF AN OCI

Basically, a Texas Instruments optically coupled isolator consists of a GaAs (gallium arsenide) light-emitting diode as the input stage and a silicon n-p-n phototransistor as the output stage. The coupling medium between diode and sensor is either an infrared-light-transmitting ("IR") glass, as used in the TIXL102/103, or simply a gas-filled gap, as used in the TIL107/108. Photons emitted from the diode (emitter) have wavelengths of about 0.9 microns. The sensor transistor responds most efficiently to photons having this same wavelength. Consequently, the input and output devices are spectrally matched for optimum transfer characteristics.

Equivalent circuits for the TIXL102/103 and TIL107/108 are shown in Figures 1 and 2. For both families of devices, a current source between the collector and base of the sensor is used to represent the virtual base current generated by incident photons striking the base. This base current is proportional to the amount of radiation emitted from the diode. The collector-base and base-emitter junction capacitances are shown for both devices since they are used to determine the rise and fall times of the output current waveform. Because a relatively large transistor base area is necessary for increased sensor efficiency, the collector-base junction capacitance is fairly large.

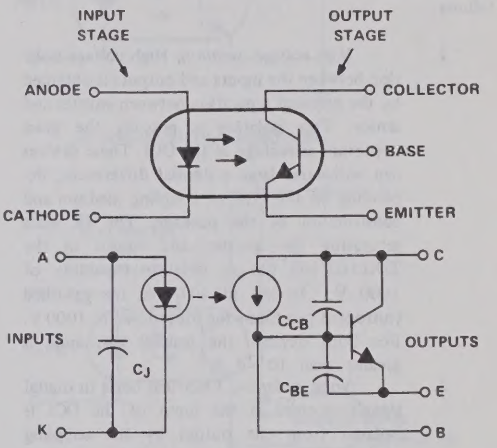


FIGURE 1. Terminal Connections and Equivalent Circuit for the TIXL102/103

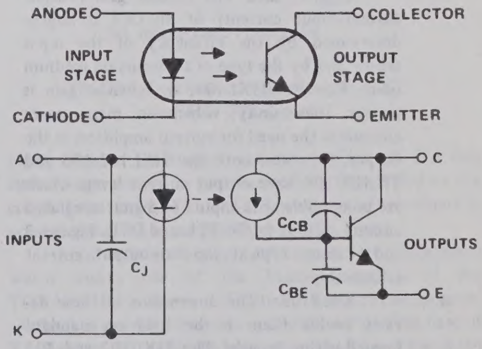


FIGURE 2. Terminal Connections and Equivalent Circuit for the TIL107/108

CHARACTERISTICS OF AN OCI

To fully utilize the advantages offered by an OCI, it is necessary that the circuit designer become aware of some of its characteristics. The difference in characteristics between the TIXL102/103 and TIL107/108 families is attributed mainly to the difference in construction.

The characteristics most useful to the designer are as follows:

1. *High voltage isolation.* High voltage isolation between the inputs and outputs is obtained by the physical separation between emitter and sensor. This isolation is possibly the most important advantage of the OCI. These devices can withstand large potential differences, depending on the type of coupling medium and construction of the package. The IR glass separating the emitter and sensor in the TIXL102/103 has an isolation capability of 1000 V. In the TIL107/108, the gas-filled (nitrogen) gap limits the breakdown to 1000 V. For both devices, the leakage resistance is greater than $10^{12}\Omega$.
2. *Noise isolation.* Electrical noise in digital signals received at the input of the OCI is isolated from the output by the coupling medium. Since the input is a diode, common-mode noise is rejected. Noise immunity for both devices is less than 1.0 V from anode to cathode.
3. *Current gain.* The current gain (output current/input current) of an OCI is largely determined by the efficiency of the n-p-n sensor and by the type of transmission medium used. For the TIXL103, the current gain is greater than unity, which in many cases eliminates the need for current amplifiers in the output. However, both the TIXL102/103 and TIL107/108 have output current levels which are compatible with inputs of digital integrated circuits such as 54/74 TTL and DTL. Figures 3 and 4 show typical input-to-output current relationships.
4. *Small size.* The dimensions of these devices enable them to be used on standard printed-wiring boards. The TIXL102 and 103 are built in a metal can similar to a transistor package while the TIL107 and 108 are made into a double-flanged package similar to two TO-18 transistor packages end to end. The physical dimensions of these packages are shown in Figures 5 and 6.

These are some of the prime characteristics of an OCI which can be used effectively to isolate two systems. Other characteristics, such as high speed (which enable OCIs to be of advantage in solid-state relays) and wide operating-temperature range, are discussed in Texas Instruments Bulletin CB-116 (available upon request).

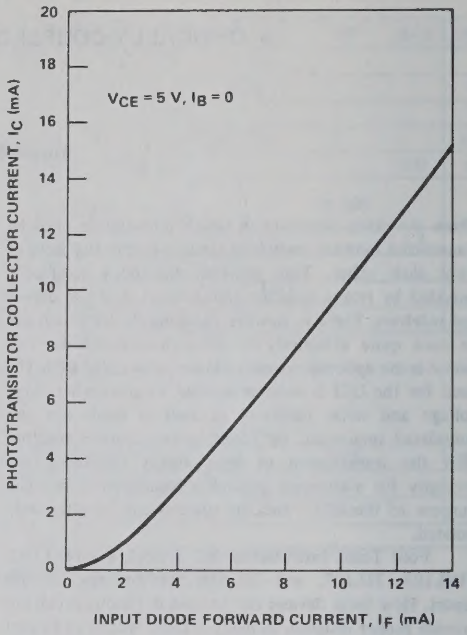


FIGURE 3. Typical Input/Output Current Relationship for the TIXL102/103

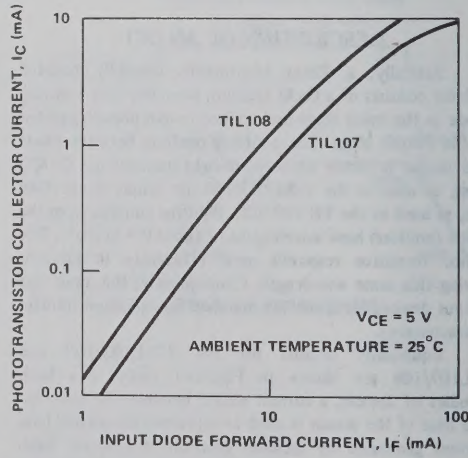
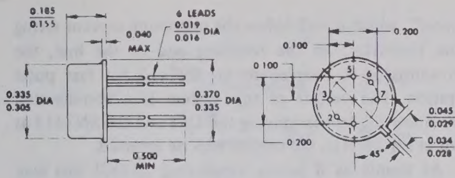


FIGURE 4. Typical Input/Output Current Relationship for the TIL107/108


0.185
0.155
6 LEADS
0.019
0.016 DIA
0.040 MAX
0.335
0.305 DIA
0.370
0.335 DIA
0.500 MIN
0.200
0.100
0 100
0 200
0.045
0.029
0.034
0.028
45°
1
2
3
5
6
7

Dimensions without tolerance designate true position. Leads having maximum diameter (0.019″) measured in gaging plane 0.054″ +0.001″ −0.000″ below the seating plane of the device shall be within 0.007″ of their true positions relative to a maximum-width tab.

ALL DIMENSIONS ARE
IN INCHES
UNLESS OTHERWISE
SPECIFIED

FIGURE 5. Physical Dimensions of the TIXL102/103

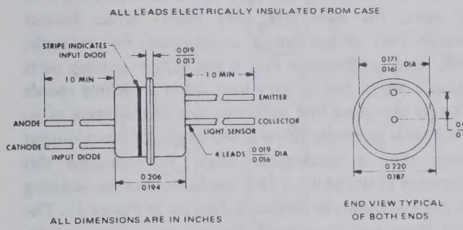
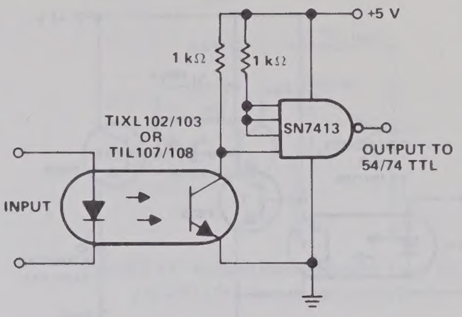
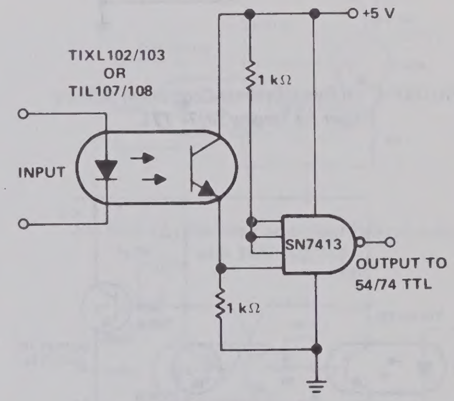

ALL LEADS ELECTRICALLY INSULATED FROM CASE
STRIPE INDICATES INPUT DIODE
0 019
0 013
1 0 MIN
1 0 MIN
EMITTER
ANODE
COLLECTOR
LIGHT SENSOR
CATHODE
INPUT DIODE
4 LEADS 0 019
0 016 DIA
0 206
0 194
0 171
0 161 DIA
0 055
0 045
0 220
0 187
END VIEW TYPICAL OF BOTH ENDS
ALL DIMENSIONS ARE IN INCHES

FIGURE 6. Physical Dimensions of the TIL107/108


+5 V
1 kΩ
1 kΩ
TIXL102/103
OR
TIL107/108
SN7413
OUTPUT TO
54/74 TTL
INPUT

(a) NON-INVERTING FUNCTION


+5 V
TIXL102/103
OR
TIL107/108
1 kΩ
INPUT
SN7413
OUTPUT TO
54/74 TTL
1 kΩ

(b) INVERTING FUNCTION

FIGURE 7. Schmitt Trigger Coupling OCI to 54/74 TTL Inputs

TYPICAL CIRCUIT APPLICATIONS

The characteristics and advantages of an OCI enable the designer to use it in a wide range of circuit applications. Important among the applications of an OCI are those involving 54/74 TTL and similar digital integrated-circuit families. As was mentioned previously, an OCI has output currents compatible with both DTL and TTL inputs. This compatibility enables it to be especially attractive as an interface element between digital systems. The device is particularly beneficial in applications where high voltage differences may exist between systems. However, it is not limited only to digital applications, as shown by the following examples.

Driving 54/74 TTL

An effective method of coupling an OCI to TTL circuitry is by using a Schmitt trigger which has an output level compatible with standard TTL devices. By coupling any of the Texas Instruments OCIs to the SN7413, as shown in Figure 7, the isolated signal at the input can be converted to TTL logic levels. Noise immunity is provided by the coupler as well as by the threshold level of the SN7413.

The OCI can also be employed as part of a Schmitt trigger circuit which utilizes discrete components. Because the output of the OCI is a transistor, it can be used as the input stage to the trigger as shown in Figure 8. For this circuit, regeneration or positive feedback is provided by the coupled emitters of T1 and T2. The output of this circuit is non-inverting and is compatible with TTL logic.

Another Schmitt trigger utilizing discrete components which makes use of the base connection of the TIXL102/103 is shown in Figure 9. In this circuit, positive feedback is provided from the collector of T2 to the base of T1. Resistor R1 limits the base current to T1 and keeps the device *off* when there is no signal at the emitter. As with the circuit in Figure 8, the output of this circuit is non-inverting and compatible with TTL levels.

Transmission-Line Isolator

By using an OCI between two systems coupled by a transmission line, effective line isolation can be achieved. Figure 10 shows a typical interface system using TTL integrated circuitry coupled by a twisted-pair line. The SN75450 is the input stage driving the transmission line and emitter of the OCI. The LED requires about 20 mA during

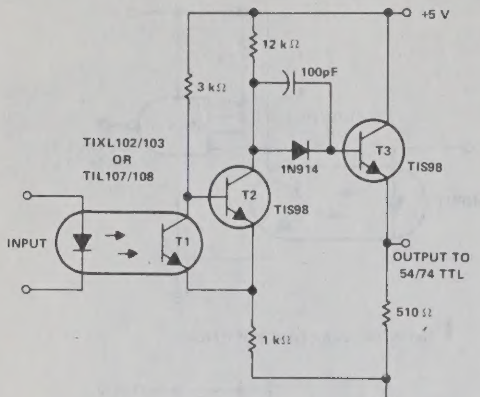

+5 V
12 kΩ
100pF
3 kΩ
TIXL102/103
OR
TIL107/108
1N914
T3
TIS98
T2
TIS98
INPUT
T1
OUTPUT TO
54/74 TTL
510 Ω
1 kΩ

FIGURE 8. OCI with Discrete-Component Schmitt Trigger for Driving 54/74 TTL

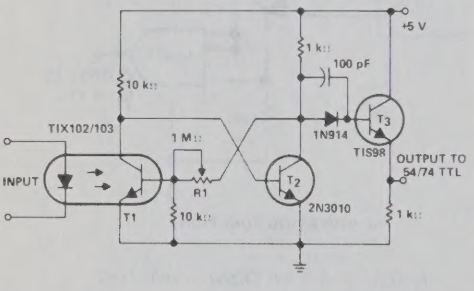

+5 V
1 kΩ
100 pF
10 kΩ
TIX102/103
1 MΩ
1N914
T3
TIS98
OUTPUT TO
54/74 TTL
INPUT
R1
T2
2N3010
T1
10 kΩ
1 kΩ

FIGURE 9. TIXL102/103 in a Schmitt Trigger for Driving 54/74 TTL

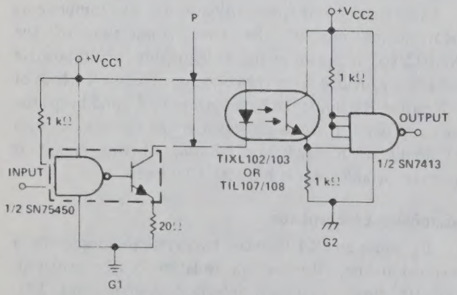

P
+VCC2
+VCC1
1 kΩ
1 kΩ
OUTPUT
INPUT
TIXL102/103
OR
TIL107/108
1/2 SN7413
1 kΩ
1/2 SN75450
20Ω
G2
G1

FIGURE 10. Typical Transmission Line Isolator

"turn-on", which is well below the maximum current rating of the transistor. At the receiving end of the line, the phototransistor is coupled to an SN7413 for fast pulse generation. The output of this system is a non-inverted pulse. However, by rearranging the OCI and the SN7413 as shown in Figure 7(a), the output may be inverted.

As simple as it seems, employing an OCI this way provides isolation for both noise and high voltage. An isolation transformer or relay could accomplish the task, but it would not be as fast as the OCI. Also, a line driver and receiver combination could be used to eliminate the noise and increase the speed, but it would be very ineffective if there were high potential differences between the input and output.

Solid-State Relay

Through the use of transistor circuits, mechanical relays are slowly being replaced by solid-state relays. In some cases, the solid-state relay (SSR) offers distinct advantages over its mechanical counterpart. For example, an SSR has the advantage that it has neither moving parts nor fragile wires. But it does have faster switching speeds and longer operating life. However, one disadvantage of an SSR is that is generally has a lower degree of input/output isolation than a mechanical relay. To overcome this disadvantage in the SSR, an OCI can be used as the isolating input stage as shown in the block diagram in Figure 11. The control stage may consist of discrete transistors or integrated circuits, while the output state consists of high-power switching devices.

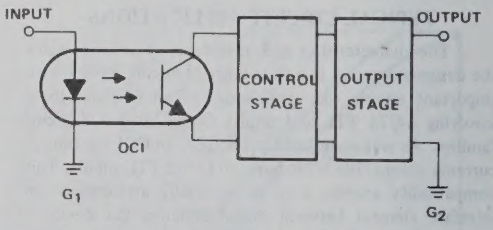

INPUT
OUTPUT
CONTROL STAGE
OUTPUT STAGE
OCI
G1
G2

FIGURE 11. Typical Solid-State Relay Using an OCI

A simple isolated latch circuit, which is somewhat of an SSR, is shown in Figure 12. The output of the OCI is used to fire the SCR which provides power to the load. To turn off the load current, the supply voltage V_{CC2} must be removed.

Isolated Chopper Circuit

Chopper circuits which use mechanical relays suffer from a speed problem as well as switching transients at the load. By using bipolar transistors or FETs as series and shunt switching elements, the speed may be improved: but capacitive coupling to the switching circuitry may still produce transient "spikes" on the output signal. By using an OCI to switch the input signal as shown in Figure 13, the

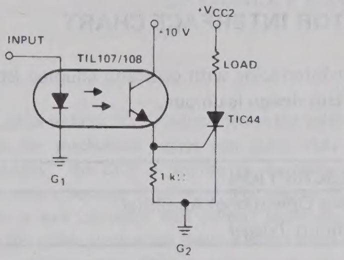

INPUT
+VCC2
+10 V
TIL107/108
LOAD
TIC44
G1
1 kΩ
G2

FIGURE 12. Solid-State Latch Using a TIL107/108

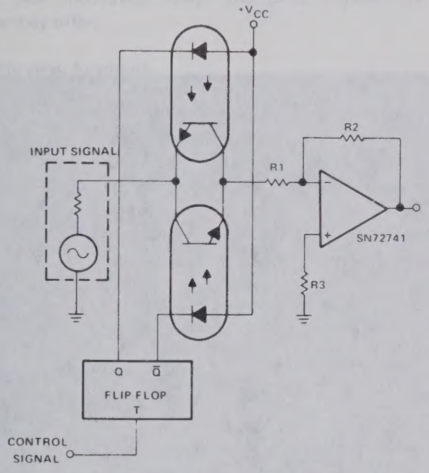

+VCC
R2
INPUT SIGNAL
R1
SN72741
R3
Q
Q̄
FLIP FLOP
T
CONTROL
SIGNAL

FIGURE 13. Chopper Circuit Using OCIs

switching circuitry can be isolated from the output, thereby reducing output "spikes". The use of two couplers in the configuration shown allows chopping of either positive or negative input signals with a frequency of one-half that of the input to the flip-flop. The SN72741 operational amplifier is used to increase the output signal with a gain of R_2/R_1.

Pulse Amplifiers

Pulse amplification, as well as isolation, can be achieved by using an OCI with a pulse amplifier. The circuit shown in Figure 14 uses an isolator with an SN72741 operational amplifier to amplify the pulse appearing at the anode of the LED. The gain of this circuit is controlled by the feedback resistor R_F. An amplifier employing discrete components and which uses the TIL102/103 as part of the current feedback pair is shown in Figure 15. The feedback resistor R_1 controls the current gain as well as the output d-c level.

Figure 16 shows an OCI with a voltage-feedback amplifier which has a gain of $1 + R_2/R_1$. This type of amplifier offers high input impedance which will not load the emitter of the sensor transistor.

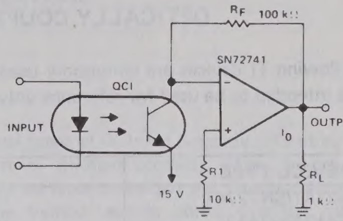

RF 100 kΩ
SN72741
OCI
INPUT
OUTPUT
Io
R1
RL
15 V
10 kΩ
1 kΩ

FIGURE 14. Isolated Pulse Amplifier Using OCI and SN72741 Operational Amplifier

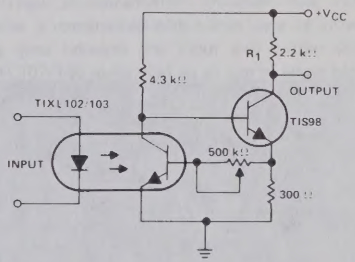

+VCC
R1
2.2 kΩ
4.3 kΩ
OUTPUT
TIXL102/103
TIS98
INPUT
500 kΩ
300 Ω

FIGURE 15. Discrete-Component Pulse Amplifier with TIXL102/103

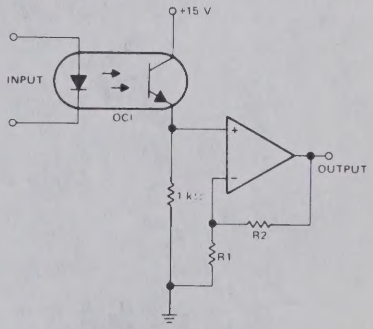
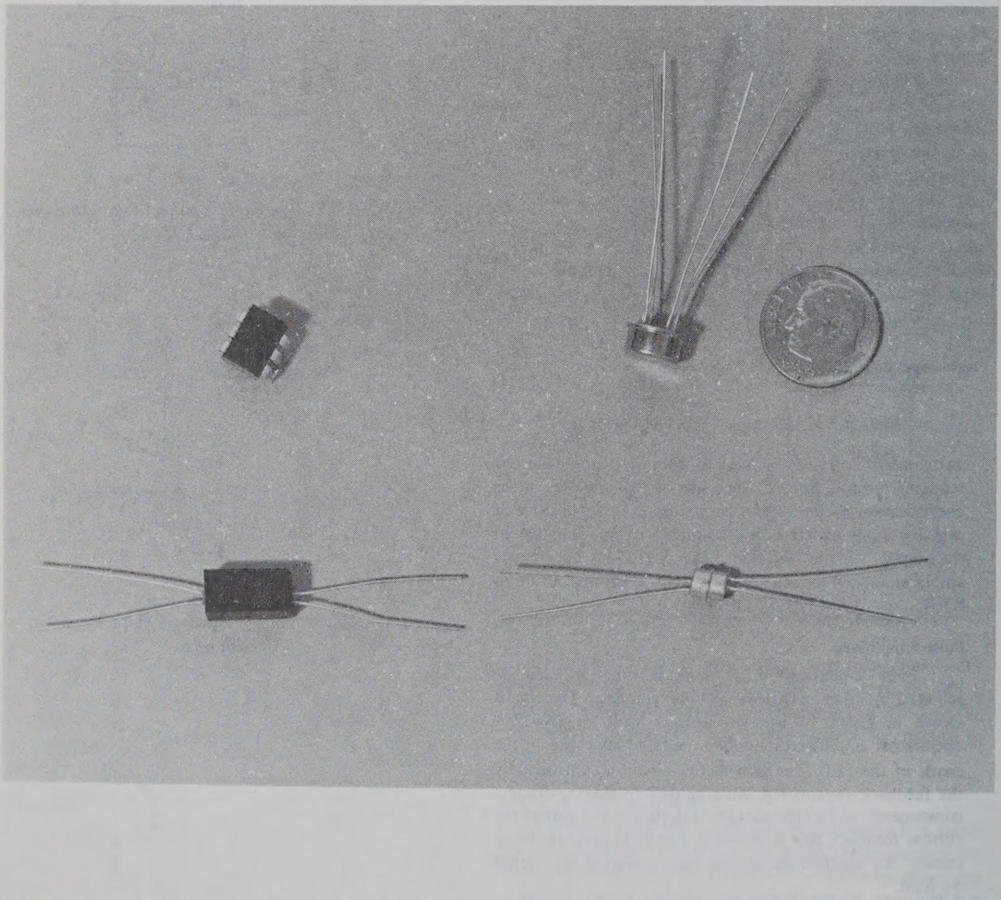

+15 V
INPUT
OCI
OUTPUT
1 kΩ
R2
R1

FIGURE 16. Voltage-Feedback Pulse Amplifier with OCI

OPTICALLY COUPLED ISOLATOR INTERFACE CHART

The following TI devices are commonly used in circuits for interfacing with optically coupled isolators. The interface chart is intended to be used for reference only since each circuit design is unique.

DEVICE TYPE	DESCRIPTION
SN52741/SN72741	High-Performance Operational Amplifier
SN5413/SN7413	Dual NAND Schmitt Trigger



OPTICALLY COUPLED ISOLATORS

The optically-coupled isolator (OCI) is designed as the solid state replacement for mechanical relays and pulse transformers. Functionally, the OCI is similar to its older mechanical counterpart because it offers a high degree of isolation between a pair of input and output terminals. However, unlike the older mechanical devices which transfer signals by magnetic coupling, OCIs transfer signals by a photon-coupling process. Briefly, OCIs are the logical choice over mechanical relays and pulse transformers because they offer:

For relay functions:

- Faster operating speeds
- Positive (no bounce) action
- Insensitiveness to vibration and shock
- Long life as there are no moving contacts to wear or pit
- Wide operating temperature range as there are no moving contacts to stick
- Small size
- Compatibility with DTL and TTL integrated circuits

For transformer functions:

- Frequency response from dc to 100 kHz
- Lower coupling capacitance for better common-mode rejection
- Small size
- Improved shock and vibration resistance

OCI CONFIGURATION

The input stage of an OCI consists of a highly efficient GaAs (gallium arsenide) light-emitting diode. When forward biased at a relatively low current level, the light-emitting diode emits photons which have an optical wavelength in the near-infrared region of about 0.9 μm.

The output stage of an OCI consists of a Si (silicon) phototransistor. This light sensitive device responds most efficiently to optical wavelengths in the 0.9 μm region, Hence, the photon-coupled input and output stages are spectrally matched for optimum input-to-output transfer ratio.

Several types of OCIs are presently offered by Texas Instruments as standard products. These devices differ primarily in the types of emitters and phototransistors used and in the method used to obtain electrical isolation. Figure 1 shows the outline drawings for both the TIXL-102/103 and the TIL107/108 series of OCIs. Note that both series of devices consist of the input-stage emitter and the output-stage phototransistor. However, the TIXL-102/103 series is constructed with a thin layer of infrared transmitting glass between the input and output stages while the TIL107/108 series used an air gap to attain higher electrical isolation.

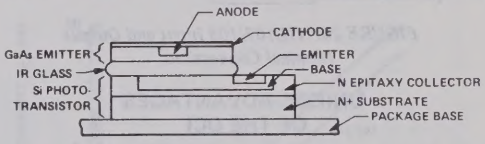


FIGURE 1a. Details of TIXL102/103 Construction

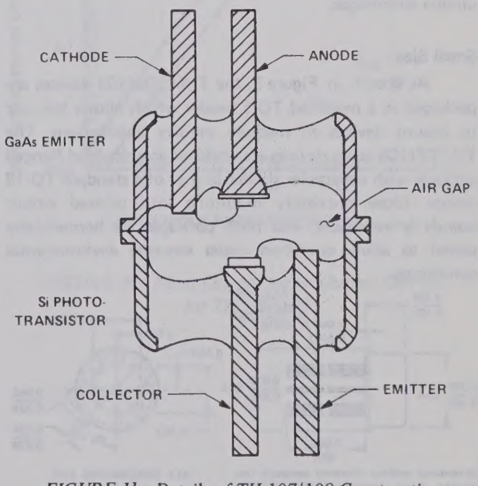


FIGURE 1b. Details of TIL107/108 Construction

OPTICALLY COUPLED ISOLATORS

Regardless of whether an air gap or IR transmitting glass is used to separate the input and output terminals, the operating characteristics are basically the same. When an input signal or forward bias current is applied to the light-emitting diode, photons are absorbed in the phototransistor, thus providing conduction between the output terminal leads. Figure 2 indicates schematically how the input and output stages of the TIXL102/103 series and TIL107/108 series are arranged.

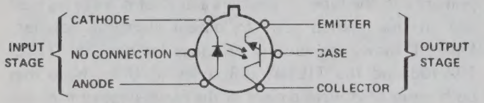


FIGURE 2a. TIXL102/103 Input and Output Terminal Connections

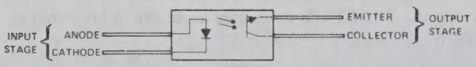


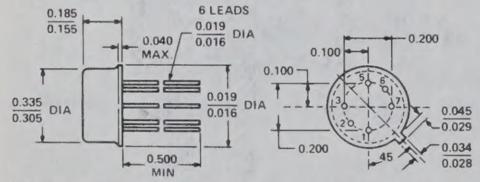
FIGURE 2b. TIL107/108 Input and Output Terminal Connections

UNIQUE ADVANTAGES OF THE OCI

Aside from the fact that OCIs are of solid state construction, and possess no moving contacts which will eventually *freeze* or wear out, they offer several other unique advantages.

Small Size

As shown in Figure 3, the TIXL102/103 devices are packaged in a modified TO-5 header which allows the user to mount devices in medium density applications. The TIL107/108 series devices are enclosed in a doubled-flanged package with a diameter similar to that of a standard TO-18 device. Close proximity mounting into printed circuit boards is attainable, and both packages are hermetically sealed to allow operation under extreme environmental conditions.



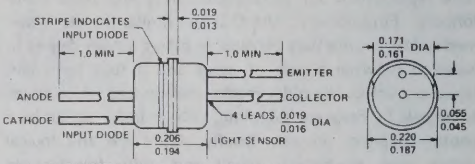
Dimensions without tolerance designate true position. Leads having maximum diameter (0.019") measured in gaging plane 0.054" +0.001" −0.000" below the seating plane of the device shall be within 0.007" of their true positions relative to a maximum-width tab.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

FIGURE 3a. Mechanical Data of TIXL102/103

High-Voltage Electrical Isolation

The voltage isolation characteristic of OCIs allows the user to transmit signals between two or more terminals within a system when large voltage potential differences exist. The TIXL102/103 series is rated at 100 volts isolation while the TIL107/108 series is capable of isolating up to 1000 volts. Since physical packaging usually limits voltage isolation capabilities, the package can be modified to attain several thousand volts isolation with multimegohm leakage resistance and picofarad coupling-capacitance.



ALL LEADS ELECTRICALLY INSULATED FROM CASE
ALL DIMENSIONS ARE IN INCHES
END VIEW TYPICAL OF BOTH ENDS

FIGURE 3b. Mechanical Data of TIL107/108

High Gain

As outlined in Table I, the TIXL102 and TIXL103 have typical input-to-output current ratios of 0.6 and 1.4 respectively. Since the TIXL103 has a gain factor greater than 1, the need for amplifiers behind the OCI output stage is eliminated. While the TIL107/108 devices have typical current gain ratios of 0.1 and 0.2 respectively, both are designed to operate with input and output currents that are compatible with standard DTL and TTL integrated circuits. Figure 4 outlines typical output currents for various input current levels.

High Speed

Table II outlines the typical switching characteristics for the TIXL102/103 and TIL107/108 series of OCIs at 25°C case temperature. Note that the rise, fall delay, and storage times for these solid state OCIs are measured in *micro*seconds. Thus, they are typically 1000 times faster than conventional mechanical relays which have switching speeds in the *milli*seconds range.

Wide Operating—Temperature Range

The GaAs input diode and the Si phototransistor have temperature coefficients that offset each other. An increase in temperature will cause the GaAs emitter to emit fewer photons while the phototransistor will increase in sensitivity. On the other hand, at low temperatures the efficiency of the GaAs emitter increases and more photons are emitted, but the phototransistor sensitivity decreases. For this reason, the overall current gain of the OCI is fairly stable over a wide temperature range. Figure 5a shows typical relative output of the TIXL102/103 series while Figure 5b shows the typical relative output current for the TIL107/108 series. Note that both sets of characteristic curves show input versus output currents over a −55°C to 125°C temperature range. This operating-range stability offers the user a wide degree of flexibility for applications which involve MIL-Spec temperatures.

OCIs are also valuable for coupling either analog or digital signals between terminals in a system. Since ground looping problems are avoided when OCIs are used, spurious noise from circulating ground currents is eliminated. In addition, the d-c isolation characteristic of OCIs will allow signal transfer, despite the fact that large voltage-potential differences may exist between the various terminals of a system.

Table I

DEVICE	TEST CONDITIONS	INPUT CURRENT	TYPICAL OUTPUT CURRENT
TIXL 102	$V_{CE} = 5$ V, $I_B = 0$	$I_F = 10$ mA	6 mA
TIXL 103	$V_{CE} = 5$ V, $I_B = 0$	$I_F = 10$ mA	14 mA
TIL 107	$V_{CE} = 5$ V	$I_F = 15$ mA $I_F = 35$ mA	1 mA 4 mA
TIL 108	$V_{CE} = 5$ V	$I_F = 15$ mA $I_F = 35$ mA	2 mA 7 mA

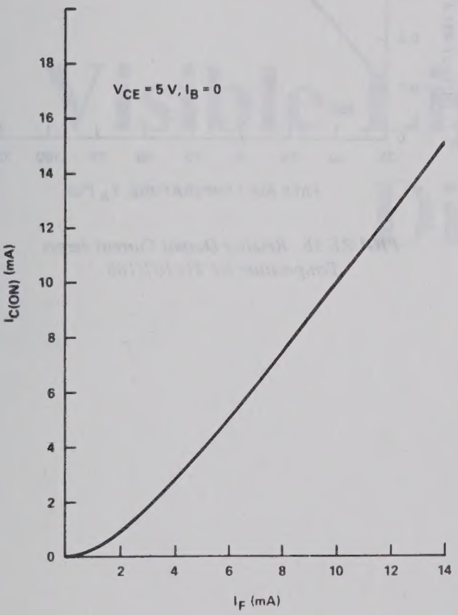


FIGURE 4a. Input Current versus Output Current for TIXL102/103

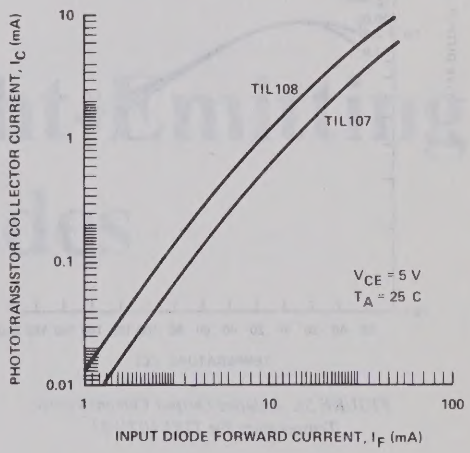


FIGURE 4b. Input Current versus Output Current for TIL107/108

Table II

DEVICE	TEST CONDITIONS	TYPICAL RISE TIME	TYPICAL STORAGE TIME	TYPICAL DELAY TIME	TYPICAL FALL TIME
TIXL 102 TIXL 103	$V_{CC} = 20$ V, $I_{C(on)} =$ 10 mA, $R_L = 100\ \Omega$	3 μs 3 μs	0.1 μs 0.1 μs	0.5 μs 0.5 μs	3 μs 3 μs
TIL 107 TIL 108	$V_{CC} = 35$ V, $I_{C(on)} =$ 500 μA, $R_L = 1$ kΩ	5 μs 5 μs	0.5 μs 0.5 μs	3 μs 3 μs	5 μs 5 μs

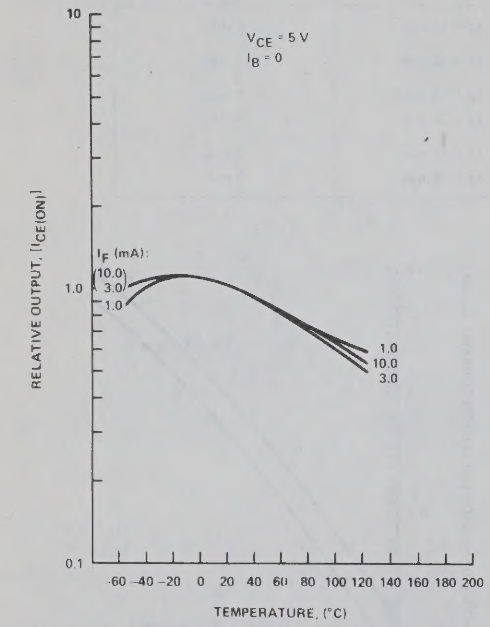


FIGURE 5a. Relative Output Current versus Temperature for TIXL102/103

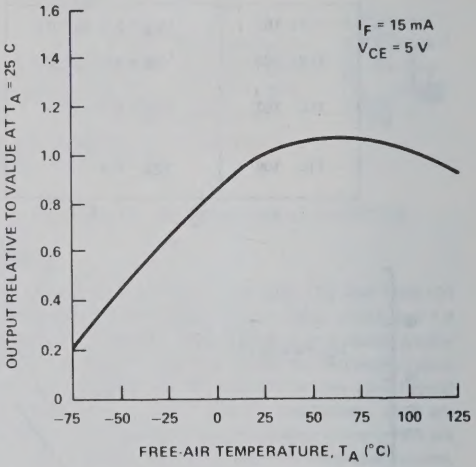


FIGURE 5b. Relative Output Current versus Temperature for TIL107/108

Visible-Light-Emitting Diodes

QUICK REFERENCE GUIDE
VISIBLE-LIGHT-EMITTING DIODES

VISIBLE-LIGHT-EMITTING DIODES QUICK REFERENCE GUIDE

DEVICE	PKG	OUTPUT			V_F		λ_P	FEATURES
		MIN	TYP	@ I_F	MAX	@ I_F	TYP	
TIL203	5 H	375 fL	750 fL	20 mA	2 V	20 mA	0.66 μm	TO-18 header. Clear epoxy dome.
TIL204	5 H	375 fL	750 fL	20 mA	2 V	20 mA	0.66 μm	TO-18 header. Red epoxy dome.
TIL205	5 I	375 fL	750 fL	20 mA	2 V	20 mA	0.66 μm	Coaxial package. Clear epoxy lens.
TIL206	5 I	375 fL	750 fL	20 mA	2 V	20 mA	0.66 μm	Coaxial package. Red epoxy lens.
TIL207	5 S	375 fL	750 fL	20 mA	2 V	20 mA	0.66 μm	TIL63 package. Clear epoxy lens.
TIL208	5 S	375 fL	750 fL	20 mA	2 V	20 mA	0.66 μm	TIL63 package. Red epoxy lens.
TIL209	5 J	15 μW		20 mA	2 V	20 mA	0.65 μm	0.120-inch-dia package. Red diffused epoxy.
TIL210	5 K	25 μW		20 mA	2 V	20 mA	0.65 μm	0.230-inch-dia package. Red diffused epoxy.

TYPES TIL203 THRU TIL208
GALLIUM ARSENIDE PHOSPHIDE VISIBLE-LIGHT SOURCES

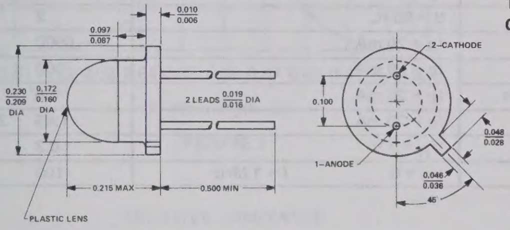
TYPES TIL203 THRU TIL208
BULLETIN NO. DL-S 7011387, SEPTEMBER 1970

DESIGNED TO EMIT VISIBLE RED LIGHT WHEN FORWARD BIASED

- Recommended for Application in Visual Indicators, Alpha-Numeric Displays, and Built-In Diagnostics
- Metal-Flanged Packages for Printed Board and Panel Mounting
- High Brightness with Solid-State Reliability
- Compatible with Most TTL and DTL Circuits
- TIL203 Formerly SL1152, TIL204 Formerly SL1148
  TIL205 Formerly SL1153, TIL206 Formerly SL1158
  TIL207 Formerly SL1151, TIL208 Formerly SL1149

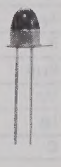
mechanical data

TIL203–CLEAR LENS
TIL204–RED LENS

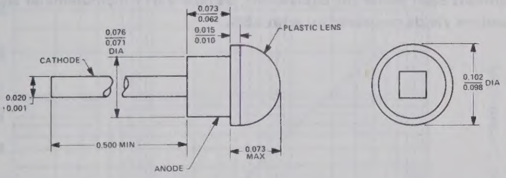

0.010
0.006
0.097
0.087
2–CATHODE
0.230
0.209
DIA
0.172
0.160
DIA
2 LEADS 0.019 / 0.016 DIA
0.100
0.048
0.028
1–ANODE
0.046
0.036
45°
0.215 MAX
0.500 MIN
PLASTIC LENS

THE CATHODE IS IN ELECTRICAL CONTACT WITH THE CASE

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



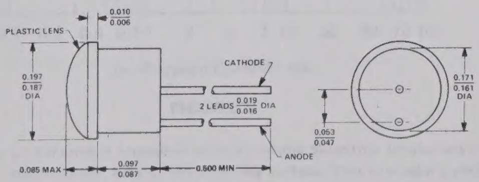
TIL205–CLEAR LENS
TIL206–RED LENS


0.073
0.062
0.015
0.010
PLASTIC LENS
0.076
0.071
DIA
CATHODE
0.020
±0.001
0.102
0.098
DIA
0.500 MIN
0.073
MAX
ANODE

THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE

ALL DIMENSIONS ARE IN INCHES

TIL207–CLEAR LENS
TIL208–RED LENS


0.010
0.006
PLASTIC LENS
0.197
0.187
DIA
CATHODE
2 LEADS 0.019 / 0.016 DIA
0.171
0.161
DIA
0.053
0.047
ANODE
0.085 MAX
0.097
0.087
0.500 MIN

BOTH LEADS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL DIMENSIONS ARE IN INCHES

TYPES TIL203 THRU TIL208
GALLIUM ARSENIDE PHOSPHIDE VISIBLE-LIGHT SOURCES

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature . . . . 3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1) . . . . 50 mA
Storage Temperature Range . . . . −40°C to 80°C
Lead Temperature 1/16 Inch from Case for 10 Seconds . . . . 230°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
L_V	Luminance (Photometric Brightness)	I_F = 20 mA,	See Notes 2 and 3	375	750		fL
I_F	Forward Current	B = 50 fL			2		mA
λ_P	Wavelength at Peak Emission	I_F = 20 mA			6600		Å
B	Spectral Bandwidth between Half-Power Points	I_F = 20 mA			200		Å
θ_{HP}	Emission Beam Angle between Half-Power Points	I_F = 20 mA			135°		
V_F	Static Forward Voltage	I_F = 20 mA			1.65	2	V
I_R	Static Reverse Current	V_R = 3 V			0.3		μA
C	Capacitance	V_F = 0,	f = 1 MHz		100		pF

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.

2. Luminance may also be measured in candelas per square foot (cd/ft^2) or candelas per square meter (cd/m^2). To convert foot-lamberts to these units use the following equivalencies: 1 fL = (1/π) cd/ft^2 = 3.4263 cd/m^2.

3. Luminance is measured with a Gamma Scientific Brightness Spot Meter (or equivalent), using a 0.011-inch-diameter spot focused on the brightest area of the emitting surface. This procedure yields repeatability with ±5%.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

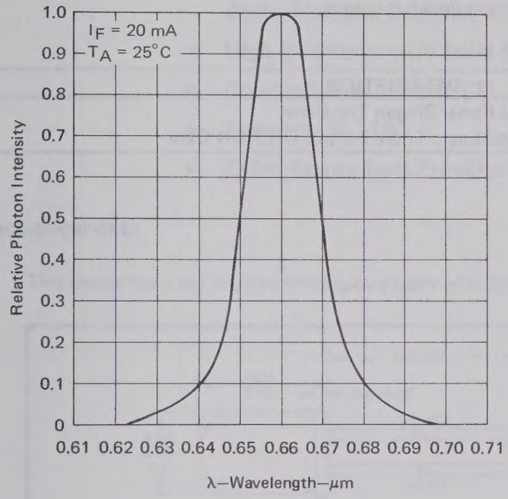


FIGURE 1

RELATIVE PHOTON INTENSITY
vs
ANGULAR DISPLACEMENT

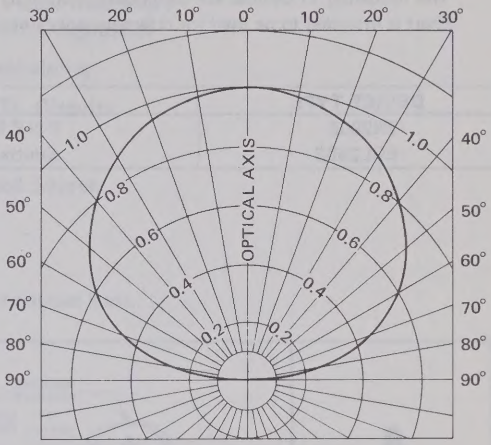


FIGURE 2

RELATIVE LUMINANCE
vs
FORWARD CURRENT

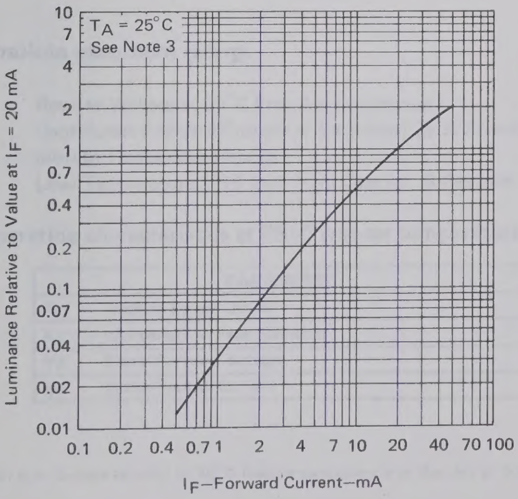


FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

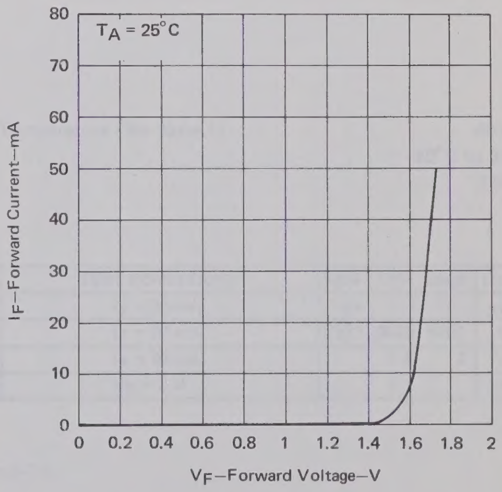


FIGURE 4

NOTE 3: Luminance is measured with a Gamma Scientific Brightness Spot Meter (or equivalent), using a 0.011-inch-diameter spot focused on the brightest area of the emitting surface. This procedure yields repeatability within ±5%.

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME
IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

VISIBLE-LIGHT-EMITTING DIODE INTERFACE CHART

The following TI devices are commonly used in circuits for interfacing with visible-light-emitting diodes. This interface chart is intended to be used for reference only since each circuit design is unique.

DEVICE TYPE	DESCRIPTION
2N2905	P-N-P Epitaxial Planar Silicon Transistor
ECL2502	Emitter-Coupled-Logic Triple 2-Input OR/NOR Gate

TYPE TIL209
GALLIUM ARSENIDE PHOSPHIDE VISIBLE-LIGHT SOURCE

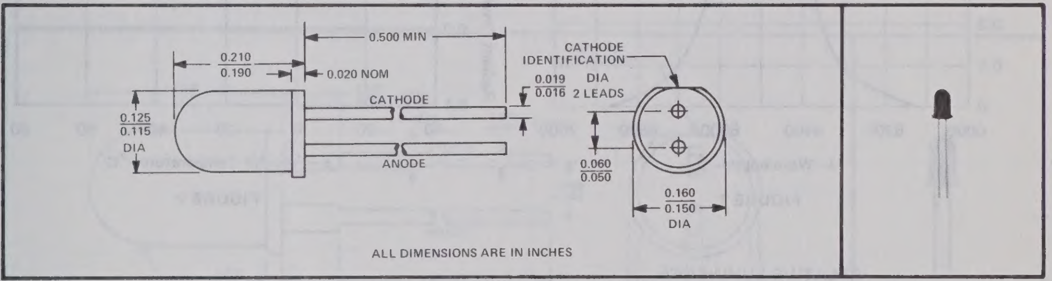
TYPE TIL209
BULLETIN NO. DL-S 7111417, FEBRUARY 1971
REVISED MARCH 1971

DESIGNED TO EMIT VISIBLE RED LIGHT WHEN FORWARD BIASED

- Recommended for Application in Visual Indicators, Alpha-Numeric Displays, and Built-In Diagnostics
- High Brightness with Solid-State Reliability
- Compatible with Most TTL and DTL Circuits
- Formerly SL1160
- Filled-Epoxy Lens Provides Diffused Source

mechanical data

This device has a red molded filled-epoxy body with silver-plated dumet leads.


0.500 MIN
0.210
0.190
0.020 NOM
CATHODE IDENTIFICATION
0.019
0.016 DIA
2 LEADS
CATHODE
0.125
0.115
DIA
ANODE
0.060
0.050
0.160
0.150
DIA
ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	40 mA
Storage Temperature Range	−40°C to 80°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	230°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 20 mA		15		μW
λ_p	Wavelength at Peak Emission	I_F = 20 mA	6300	6500	6700	Å
V_F	Static Forward Voltage	I_F = 20 mA		1.6	2	V
I_R	Static Reverse Current	V_R = 3 V		0.1		μA

NOTE 1: Derate linearly to 70°C free-air temperature at the rate of 0.89 mA/°C.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

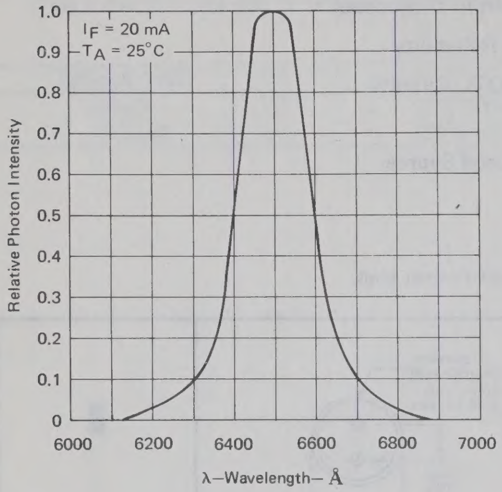


FIGURE 1

RELATIVE RADIANT POWER OUTPUT vs FREE-AIR TEMPERATURE

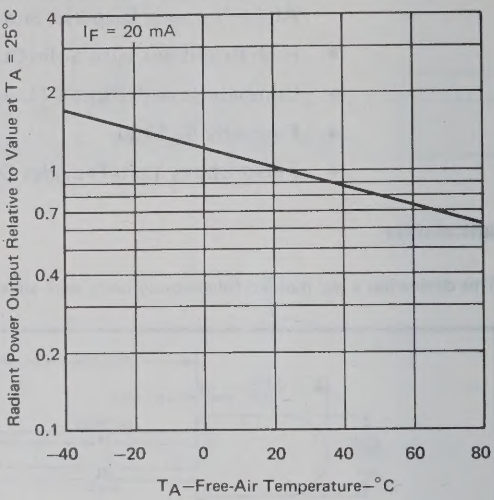


FIGURE 2

RELATIVE LUMINANCE vs FORWARD CURRENT

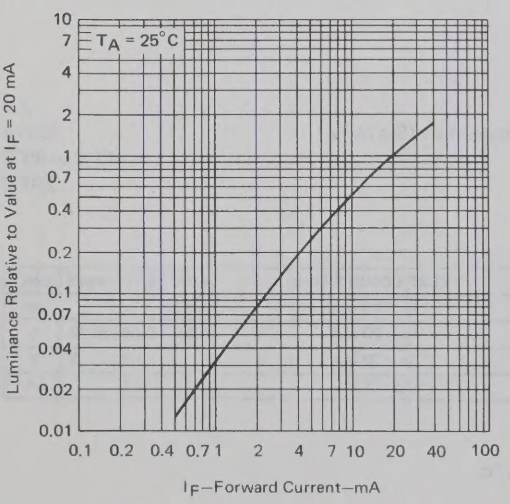


FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

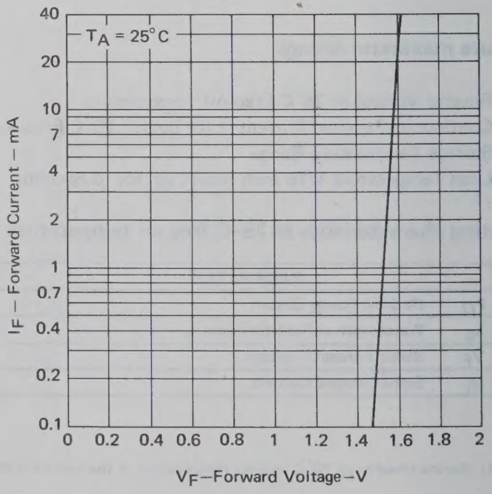


FIGURE 4

PRINTED IN U.S.A.

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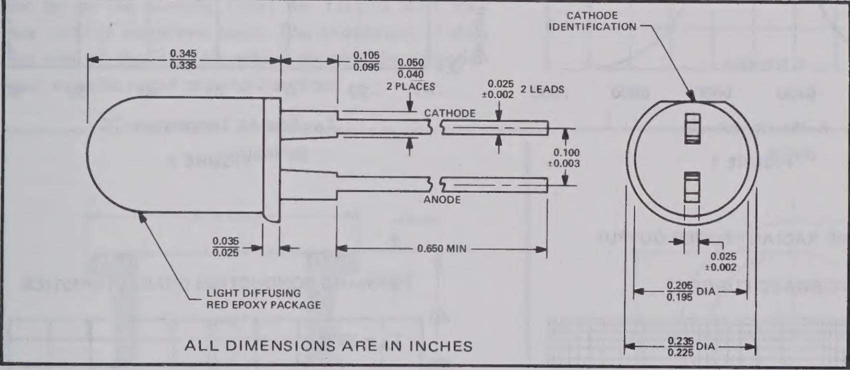
GALLIUM ARSENIDE PHOSPHIDE VISIBLE-LIGHT SOURCE

DESIGNED TO EMIT VISIBLE RED LIGHT WHEN FORWARD BIASED

- Recommended for Panel Mounted Visual Indicators
- High Brightness with Solid-State Reliability
- Compatible with Most TTL and DTL Circuits
- Leads Are Designed to be Wire-Wrapped
- Filled-Epoxy Lens Provides Diffused Source

mechanical data

This device has a red molded filled-epoxy body with square tin-plated kovar (or equivalent) leads.


CATHODE IDENTIFICATION
0.345
0.335
0.105
0.095
0.050
0.040
2 PLACES
0.025
±0.002
2 LEADS
CATHODE
0.100
±0.003
ANODE
0.035
0.025
0.650 MIN
0.025
±0.002
0.205
0.195
DIA
LIGHT DIFFUSING
RED EPOXY PACKAGE
0.235
0.225
DIA

ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	40 mA
Storage Temperature Range	−40°C to 80°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	230°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 20 mA	25			µW
λ_p	Wavelength at Peak Emission	I_F = 20 mA	6300	6500	6700	Å
V_F	Static Forward Voltage	I_F = 20 mA		1.6	2	V
I_R	Static Reverse Current	V_R = 3 V		0.1		µA

NOTE 1: Derate linearly to 70°C free-air temperature at the rate of 0.89 mA/°C.

TYPE TIL210
GALLIUM ARSENIDE PHOSPHIDE VISIBLE-LIGHT SOURCE

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

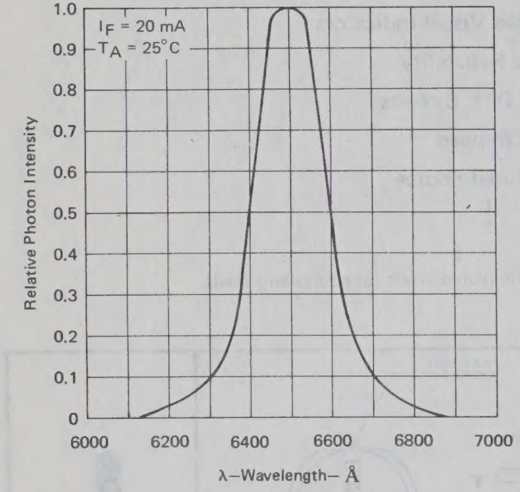


FIGURE 1

RELATIVE RADIANT POWER OUTPUT
vs
FREE-AIR TEMPERATURE

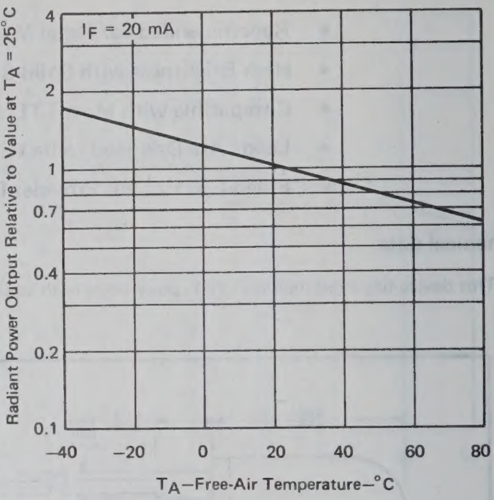


FIGURE 2

RELATIVE RADIANT POWER OUTPUT
vs
FORWARD CURRENT

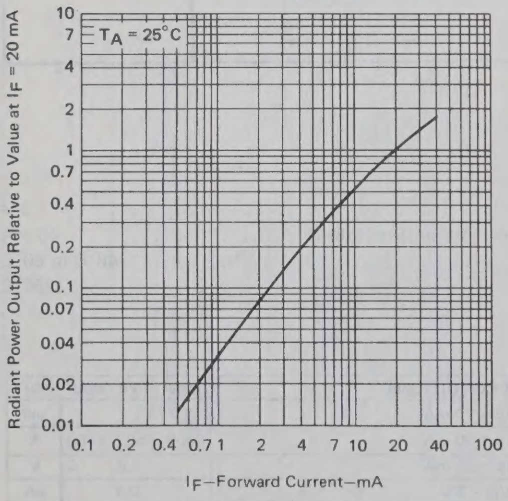


FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

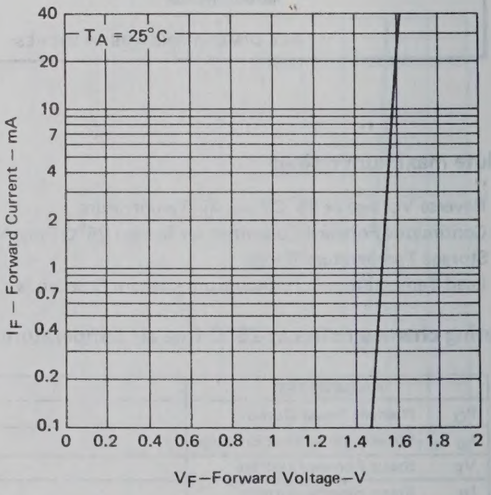


FIGURE 4

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME
IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

MOUNTING CLIP FOR TIL210 VISIBLE-LIGHT-EMITTING DIODE

MOUNTING CLIP FOR TIL210 VLED
BULLETIN NO. DL-S 7211684, MARCH 1972

description

This specification outlines the instructions to be followed when mounting the TIL210 visible-light-emitting diode in 0.062-inch-thick or 0.125-inch-thick panels. An illustration of the mounting bushing and its adapter ring is shown in Figure 1. Dimensions are outlined in Figure 2.

To mount the clip in a 0.125-inch-thick panel, it is first necessary to drill a 17/64-inch-diameter hole and remove the extruded burr. Remove and discard the adapter ring. Insert the bushing (see Figure 3) through the front of the panel. while holding the bushing in place, insert the TIL210 from the rear of the panel until the VLED snaps into place. The orientation of the flat side of the TIL210, which denotes the cathode lead, must be noted prior to insertion.

For mounting in a 0.062-inch-thick panel, drill a 17/64-inch-diameter hole and remove the extruded burr, leaving a hole with sharp corners. Separate the bushing from its adapter ring and insert the bushing through the front of the panel. While holding the bushing in place, press the adapter ring (see Figure 3) from the rear of the panel over the bushing. Holding the lip on the bushing, insert the TIL210 from the rear until it snaps into place. The orientation of the flat side of the TIL210, which denotes the cathode lead, must be noted prior to insertion.

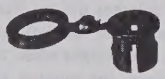
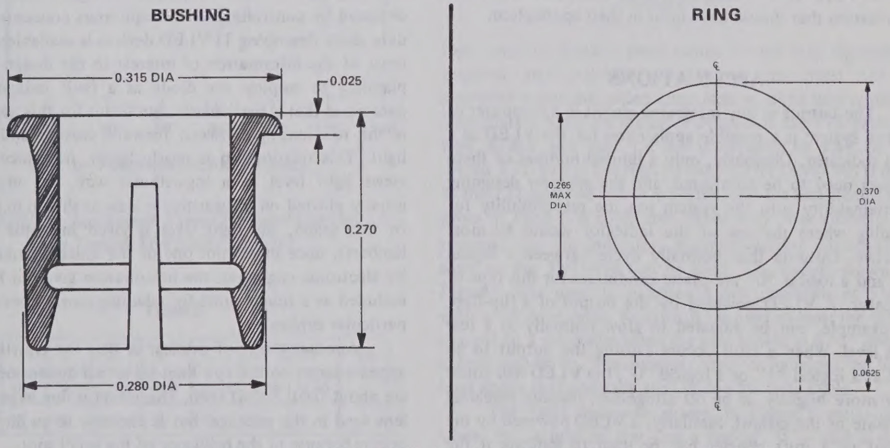


FIGURE 1



BUSHING

RING

ALL DIMENSIONS ARE IN INCHES AND ARE NOMINAL UNLESS OTHERWISE NOTED

FIGURE 2

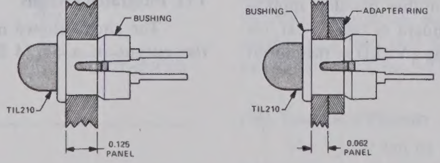


FIGURE 3

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

OPTOELECTRONIC FAULT INDICATOR FOR LOGIC CIRCUITS

Roland Windecker

Before the invention of the transistor, most switching functions were performed by electro-mechanical relays. Today these functions are performed largely by integrated circuits because of their versatility, speed, size, reliability, and other features. The relay did have one attractive feature, however, that the integrated circuit does not have: that is, the logical state of the relay could easily be determined by simply looking at the contact mechanism. Since semiconductor switches do not have such a built-in indicator, usually meters or oscilloscopes are used to determine the state of an output when troubleshooting is necessary. In some cases, the number of outputs to be monitored, the fact that a gate circuit does not appear at one of the circuit-board terminals, or simply that test equipment is not always readily available, may make the use of such methods impractical. It is the purpose of this application report to suggest the use of visible-light-emitting diodes (VLED's) as indicators in such cases, and to provide information that should be helpful in their application.

APPLICATIONS

The output of any integrated circuit in a computer or control system is a possible application for the VLED as a fault indicator. Obviously, only a limited number of these outputs need to be monitored, and the engineer designing maintainability into the system has the responsibility for deciding where the use of the indicator would be most effective. Outputs that normally cycle between a logical "1" and a logical "0" are prime candidates for this type of indicator. A VLED powered by the output of a flip-flop, for example, can be adjusted to glow normally at a low light level. When a fault occurs causing the output to be held at a logical "1" or a logical "0", the VLED will either glow more brightly or be off altogether, thereby revealing the state of the output. Similarly, a VLED powered by the output of a shift register can be used to indicate if the information is circulating normally (medium light intensity), is locked at a logical "1" (no light), or is locked at a logical "0" (full brilliance).

The use of the VLED to monitor command signals in computer or control systems is another possible application. The strobe signal from a keyboard or tape reader, for example, can be monitored by using a VLED at the output gate. Similarly, command signals used to control the flow of information between pieces of equipment can be monitored so that when trouble occurs, the fault can be isolated quickly.

In addition to computer and control system applications, VLED's can be powered directly by integrated-circuit outputs for other purposes, such as training personnel to understand logic circuits, helping the design engineer develop complex logic circuits, and reading outputs of test consoles used to diagnose and trouble shoot computer systems.

VLED CHARACTERISTICS

The VLED is a diode that emits visible light when forward biased. A single-crystal compound of gallium, arsenic, and phosphorous is used for the semiconductor element, and the color of the emitted light (red, 6600 Å) is obtained by controlling the phosphorous concentration. A data sheet describing TI VLED devices is available and gives most of the information of interest to the design engineer planning to employ the diode as a fault indicator. One parameter that is particularly significant for this application is the relationship between forward current and emitted light. This relationship is nearly linear, but since the eye views light level in a logarithmic way, the intensity is usually plotted on a logarithmic scale as shown in Figure 1. In this graph, the light level is given in terms of foot-lamberts; since this is not one of the units frequently used by electronic engineers, the information given in Table 1 is included as a rough guide for selecting current needed for a particular application.

Another point of interest is that the emitting wafer appears larger to the eye than its actual dimensions, which are about 0.01 × 0.01 inch. This effect is due in part to the lens used in the package, but is also due to an illusion that occurs because of the brilliance of the small spot.

TYPICAL CIRCUITS

TTL Integrated Circuits

The circuit shown in Figure 2 can be used to monitor the output of a 54/74 TTL integrated circuit or similar

Table 1. Relative Light Intensity Versus Current

Forward Current (mA)	Diode Light Intensity in Normal Room Lighting
0.4	Light is definitely visible.
1.0	Light is easily seen.
5.0	Light is sufficient to attract the attention of a casual observer.
10.0	Light is easily seen from a distance of twenty feet.

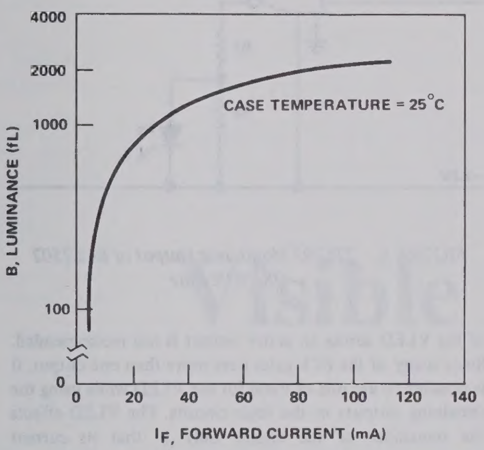


FIGURE 1. Luminance Versus Forward Current for a Typical TI VLED (TIL203)

Table 2

I_D(mA)	.5	1	2	4	6	8	10	14
R(kΩ)	6.5	3.2	1.6	0.8	0.51	0.39	0.30	
Fan-Out	9	9	8	7	6	5	3	1

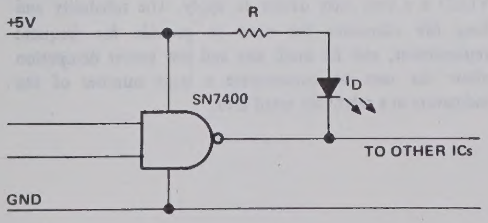


FIGURE 2. Circuit used to Monitor Gate of TTL IC

Table 3

I_D(mA)	10	15	20	25	30	40	45
R(Ω)	309	200	160	125	100	73	62
Fan-Out	33	.20	17	14	11	5	1

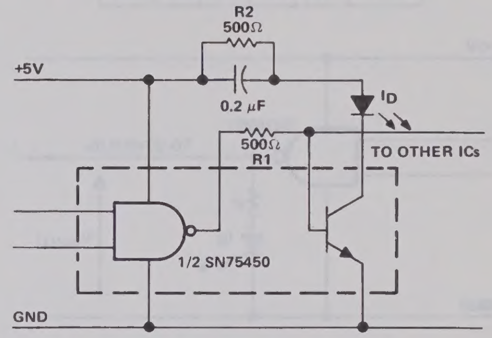


FIGURE 3. Circuit Used to Monitor Gate of a TTL IC Operating at 5 kHz with 5% Duty Cycle

logic circuits. Table 2 gives values for the limiting resistor required and includes the fan-out that must not be exceeded when the added lamp load is taken into account. This chart is based on the assumption that the TTL gate can sink 16 mA and that 1.6 mA is required by each of the driven TTL gates. If a high-current buffer (SN7440) is used as the TTL gate, 48 mA is available, and the expanded chart given in Table 3 is applicable. When very large currents are required for the indicator, a gate-transistor combination such as the SN75450 can be used. The circuit shown in Figure 3 was used to monitor a gate operating at 5 kHz with a 5% duty cycle. Resistor R2 is used to limit the diode current to a safe value when the gate is held at a "1" due to a fault condition. The bypass capacitor increases the light level above that normally seen with a 5% duty cycle.

The fault indicator shown in Figure 1 emits light when the output is low – at a logical "0" – and is dark when the output is high – at a logical "1". If the inverse response is required, that is, light when the output is high and no light when the output is low, the circuit shown in Figure 4 can be used. Table 4 gives corresponding series resistance and gate output voltage. Fan-out is not affected by this configuration, but care must be used in limiting the current to a level that does not reduce the output voltage below the recommended level.

DTL Integrated Circuits

The VLED can be used to indicate trouble with DTL integrated circuits as well as with TTL. Figure 5 and Table 5 illustrate the use of a TIL203 to monitor a 4-input NAND gate, type SN15830N.

Table 4

I_D(mA)	0.3	0.5	0.75	1.0	1.5
R(kΩ)	6.9	3.9	2.5	1.7	1.3
$V_{out(1)}$	3.62	3.6	3.52	3.5	3.46

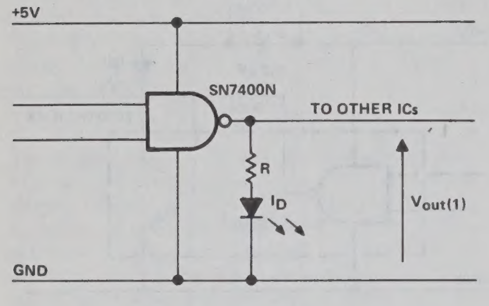


FIGURE 4. Fault Indicator Circuit which Emits Light at Logical "0" and is Dark at Logical "1"

Table 5

I_D(mA)	.5	1	2	4	6	8	10
R(kΩ)	6.7	3.2	1.6	.8	.52	.38	.29
Fan-Out	8	7	7	5	4	2	1

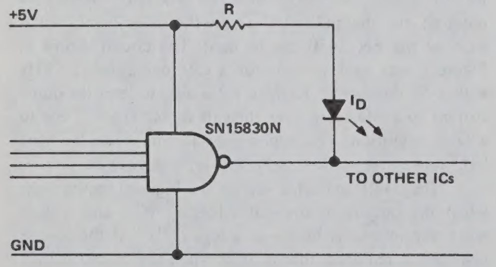


FIGURE 5. TIL203 Monitoring an SN15830N 4-Input NAND Gate

ECL Integrated Circuits

Since the voltage swing at the output of an ECL gate is approximately 0.8 volts (–0.4 to +0.4), the application of the VLED across an active output is not recommended. Since many of the ECL gates have more than one output, it is possible to use one of these for the VLED while using the remaining outputs in the logic circuits. The VLED affects the remainder of the circuit only in that its current contributes to the power dissipation in the ECL chip. Figure 6 shows a VLED monitoring the output of an ECL2502 OR/NOR gate.

Table 6

I_D(mA)	0.8	1.6	2.0
R1(Ω)	910	500	300
R2(Ω)	1000	510	330

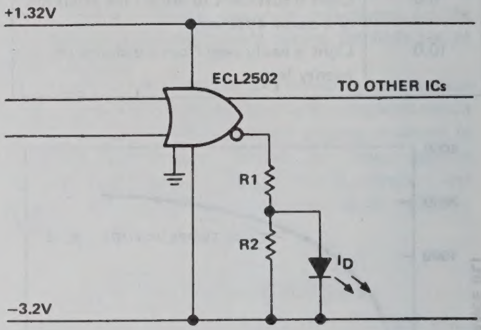


FIGURE 6. TIL203 Monitoring Output of ECL2502 OR/NOR Gate

ADDITIONAL APPLICATIONS

The circuits presented here are intended to suggest a variety of configurations for applying the VLED as a fault indicator and to illustrate the simplicity of such circuits when used on integrated circuit gates. If a few basic limitations are kept in mind, such as the maximum continuous current and maximum reverse breakdown, the VLED is a very easy device to apply. The reliability and long life eliminate the need to provide for frequent replacement, and its small size and low power dissipation allow the user to concentrate a large number of the indicators in a relatively small area.

Visible Displays

9

VISIBLE DISPLAYS
QUICK REFERENCE GUIDE

DEVICE	LUMINOUS INTENSITY PER SEGMENT OR PER DIODE		V_F PER SEGMENT		FEATURES
	TYP @	I_F	TYP @	I_F	
TIL301	90 µcd	10 mA	1.65 V	10 mA	0.1-inch-high numeric display in TO-99 hermetically sealed window can.
TIL302	100 µcd	20 mA	3.4 V	20 mA	0.25-inch-high numeric display with decimal point in 14-lead dual-in-line plastic package.
TIL303	100 µcd	20 mA	3.4 V	20 mA	Same as TIL302 except right-hand decimal point.
TIL304	100 µcd	20 mA	3.4 V	20 mA	Polarity and overflow unit.
TIL305	50 µcd	10 mA	1.65 V	10 mA	0.3-inch-high alpha-numeric character display in 5 X 7 dot matrix. 14-pin dual-in-line package.
TIL306	100 µcd	*	*	*	0.25-inch-high numeric display with logic in 16-pin dual-in-line package. Logic includes decade counter, latch, current source driver, and decoder.
TIL307	100 µcd	*	*	*	Same as TIL306 except right-hand decimal point.
TIL308	100 µcd	*	*	*	Same as TIL306 except logic chip does not include decade.
TIL309	100 µcd	*	*	*	Same as TIL308 except right-hand decimal point.
TIL310	90 µcd	10 mA	1.65 V	10 mA	0.1-inch-high numeric display in hermetically sealed flat package.
TIL311	50 µcd	*	*	*	0.27-inch-high hexadecimal display with integral logic in 14-pin dual-in-line package
TIL360	16 µcd**	10 mA**	1.65 V	10 mA	Six 0.1-inch-high numeric displays in 14-pin dual-in-line package. Units are stackable to obtain number of displays desired.

*Contains integral logic

**Pulsed operation: I_{FM} = 10 mA, t_w = 40 µs, duty cycle = 1/6.

TYPE TIL301
7-SEGMENT NUMERIC DISPLAY

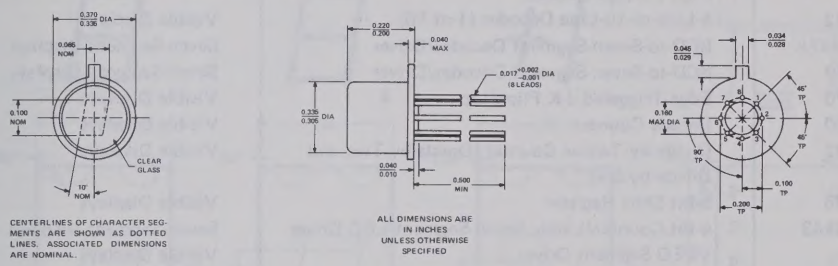
TYPE TIL301
BULLETIN NO. DL-S 7111565, SEPTEMBER 1971

SOLID-STATE MONOLITHIC VISIBLE RED DISPLAY

- Hermetic Package
- High Brightness
- Low Power Requirements
- Shock Resistant
- Single-Plane Visibility

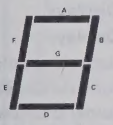
mechanical data

The display is in a welded case similar to TO-99 with a clear glass window in the top of the case. All TO-99 registration notes also apply to this outline.



CENTERLINES OF CHARACTER SEGMENTS ARE SHOWN AS DOTTED LINES. ASSOCIATED DIMENSIONS ARE NOMINAL.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



PIN 1	ANODE F	PIN 5	ANODE C
PIN 2	ANODE E	PIN 6	ANODE G
PIN 3	ANODE D	PIN 7	ANODE B
PIN 4	COMMON CATHODE	PIN 8	ANODE A

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature	4 V
Peak Forward Current, Each Segment (See Note 1)	150 mA
Continuous Forward Current, Each Segment	20 mA
Continuous Power Dissipation, Total Package	300 mW
Operating Free-Air Temperature Range	0°C to 70°C
Storage Temperature Range	−55°C to 100°C

9

operating characteristics of each segment at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
L_V	Luminance (Photometric Brightness, See Note 2 and 3)	I_{FM} = 20 mA, t_w = 40 μs, duty cycle = 1/13	100	150		fL
λ_P	Wavelength at Peak Emission		6300	6500	6700	Å
B	Spectral Bandwidth between Half-Power Points			200		Å
V_F	Static Forward Voltage	I_F = 5 mA		1.65	1.9	V
I_R	Static Reverse Current	V_R = 4 V			100	μA

NOTES:
1. This value applies for PRR $\geqslant$ 100 Hz, duty cycle $\leqslant$ 1/13.
2. Luminance may also be measured in candelas per square foot (cd/ft^2) or candelas per square meter (cd/m^2). To convert foot-lamberts to these units use the following equivalencies: 1 fL = $(1/\pi)$ cd/ft^2 = 3.4263 cd/m^2.
3. Luminance is measured with a Photo Research Brightness Spot Meter (or equivalent).

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VISIBLE DISPLAY INTERFACE CHART

The following TI devices are commonly used in circuits for interfacing with visible displays. This interface chart is intended to be used for reference only since each circuit design is unique.

DEVICE TYPE	DESCRIPTION	USED WITH
2N3980	P-N Planar Unijunction Silicon Transistor	Visible Displays
2N5449	N-P-N Epitaxial Planar Silicon Transistor	Visible Displays
A5T2907	P-N-P Epitaxial Planar Silicon Transistor	Visible Displays
SN5404/SN7404	Hex Inverter	Visible Displays
SN54L04/SN74L04	Low-Power Hex Inverter	Visible Displays
SN5416/SN7416	Hex Inverter Buffer/Driver with Open-Collector High-Voltage Outputs	Visible Displays
SN5442/SN7442	4-Line-to-10-Line Decoder (1 of 10)	Visible Displays
SN5447A/SN7447A	BCD-to-Seven-Segment Decoder/Driver	Seven-Segment Displays
SN5449/SN7449	BCD-to-Seven-Segment Decoder/Driver	Seven-Segment Displays
SN5470/SN7470	Edge-Triggered J-K Flip-Flop	Visible Displays
SN5490/SN7490	Decade Counter	Visible Displays
SN5492/SN7492	Divide-by-Twelve Counter (Divide-by-Two and Divide-by-Six)	Visible Displays
SN5496/SN7496	5-Bit Shift Register	Visible Displays
SN54143/SN74143	4-Bit Counter/Latch, Seven-Segment LED Driver	Seven-Segment Displays
SN75491	VLED Segment Driver	Visible Displays
SN75492	VLED Digit Driver	Visible Displays
TMS 1802 NC	One-Chip Calculator Circuit	Visible Displays
TMS 2500 JC, NC	2560-Bit Static Read-Only Memory	Alpha-Numeric Displays
TMS 2900 JC, NC	1280-Bit Static Read-Only Memory	Alpha-Numeric Displays
TMS 4100 JC, NC	Character Generator	Alpha-Numeric Displays

TYPES TIL302, TIL303, TIL304
BULLETIN NO. DL-S 7211470, APRIL 1971
REVISED MARCH 1972

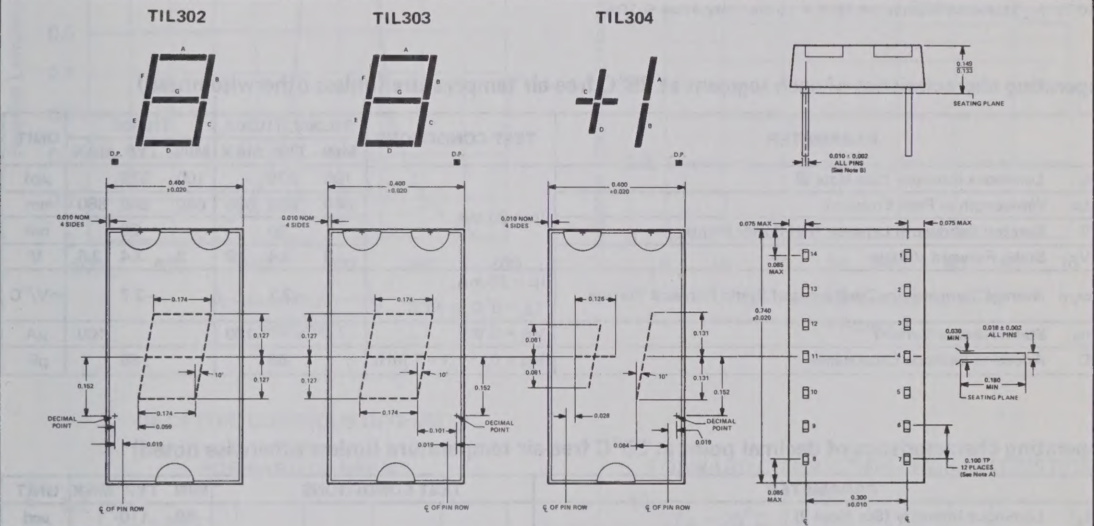
SOLID-STATE VISIBLE DISPLAY FAMILY WITH CLEAR TRANSPARENT PLASTIC ENCAPSULATION

- 0.270" High Characters
- High Brightness
- Low Power Requirements
- Sign, Overflow, Left or Right Decimal Capability
- Single-Plane Wide-Angle Visibility
- Compatible with Most TTL and DTL Circuits
- Each Unit Visually Checked for Uniformity of Elements

mechanical data

The displays are mounted on lead-frame assemblies which are then cast within a clear, electrically nonconductive, transparent plastic compound. Displays are also available in a red transparent plastic compound.

Multiple displays may be mounted on 0.450-inch centers.


TIL302
TIL303
TIL304
A
B
C
D
E
F
G
D.P.
0.400 ±0.020
0.010 NOM 4 SIDES
0.174
0.127
0.152
10°
DECIMAL POINT
0.059
0.019
0.101
0.126
0.061
0.131
0.028
0.084
℄ OF PIN ROW
0.140 / 0.133
SEATING PLANE
0.010 ± 0.002 ALL PINS (See Note B)
0.075 MAX
0.085 MAX
0.740 ±0.020
0.030 MIN
0.018 ± 0.002 ALL PINS
0.180 MIN
0.100 TP 12 PLACES (See Note A)
0.300 ±0.010

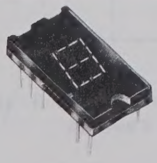
PIN 1 – CATHODE A
PIN 2 – CATHODE F
PIN 3 – ANODE E, F, G, & DECIMAL
PIN 4 – OMITTED
PIN 5 – OMITTED
PIN 6 – CATHODE DECIMAL
PIN 7 – CATHODE E
PIN 8 – CATHODE D
PIN 9 – ANODE C, D
PIN 10 – CATHODE C
PIN 11 – CATHODE G
PIN 12 – OMITTED
PIN 13 – CATHODE B
PIN 14 – ANODE A, B

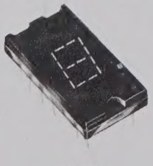
PIN 1 – CATHODE A
PIN 2 – ANODE A, F
PIN 3 – CATHODE F
PIN 4 – CATHODE G
PIN 5 – OMITTED
PIN 6 – CATHODE E
PIN 7 – ANODE D, E, DECIMAL
PIN 8 – CATHODE D
PIN 9 – CATHODE C
PIN 10 – CATHODE DECIMAL
PIN 11 – OMITTED
PIN 12 – OMITTED
PIN 13 – ANODE B, C, G
PIN 14 – CATHODE B

PIN 1 – ANODE C, D
PIN 2 – OMITTED
PIN 3 – OMITTED
PIN 4 – OMITTED
PIN 5 – OMITTED
PIN 6 – OMITTED
PIN 7 – CATHODE D
PIN 8 – CATHODE C
PIN 9 – CATHODE DECIMAL
PIN 10 – CATHODE B
PIN 11 – CATHODE A
PIN 12 – OMITTED
PIN 13 – OMITTED
PIN 14 – ANODE A, B, DECIMAL

END AND BOTTOM VIEWS AND TERMINAL DETAIL FOR ALL THREE TYPES

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within ±0.010 of its true longitudinal position relative to pins 4 and 11.
B. Lead dimensions are not controlled above the seating plane.
C. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
D. All dimensions are in inches unless otherwise specified.


TIL302


TIL303

TIL304

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature:

Each Segment	6 V
Decimal Point	3 V
Peak Forward Current, Each Segment or Decimal Point (See Note 1)	200 mA
Continuous Forward Current:	
Each Segment or Decimal Point	30 mA
Total for TIL302, TIL303	240 mA
Total for TIL304	150 mA
Operating Free-Air Temperature Range	0°C to 70°C
Storage Temperature Range	−55°C to 100°C

NOTE 1: This value applies for PRR ⩾ 60 Hz, duty cycle ⩽ 10%.

operating characteristics of each segment at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIL302, TIL303			TIL304			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
I_v	Luminous Intensity (See Note 2)	I_F = 20 mA	100	275		100	275		µcd
λ_P	Wavelength at Peak Emission		640	660	680	640	660	680	nm
B	Spectral Bandwidth between Half-Power Points			20			20		nm
V_F	Static Forward Voltage		3	3.4	3.8	3	3.4	3.8	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 20 mA, T_A = 0°C to 70°C		−2.7			−2.7		mV/°C
I_R	Static Reverse Current	V_R = 6 V			100			100	µA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		85			85		pF

operating characteristics of decimal point at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_v	Luminous Intensity (See Note 2)	I_F = 20 mA	40	110		µcd
λ_P	Wavelength at Peak Emission		645	665	685	nm
B	Spectral Bandwidth between Half-Power Points			20		nm
V_F	Static Forward Voltage		1.5	1.65	2	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 20 mA, T_A = 0°C to 70°C		−1.4		mV/°C
I_R	Static Reverse Current	V_R = 3 V			100	µA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		120		pF

NOTE 2: Luminous intensity is measured with a solar cell and filter combination which approximates the CIE (International Commission on Illumination) eye-response curve.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

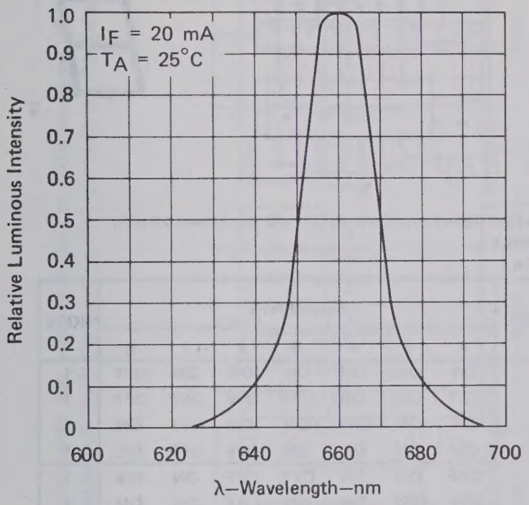


FIGURE 1

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

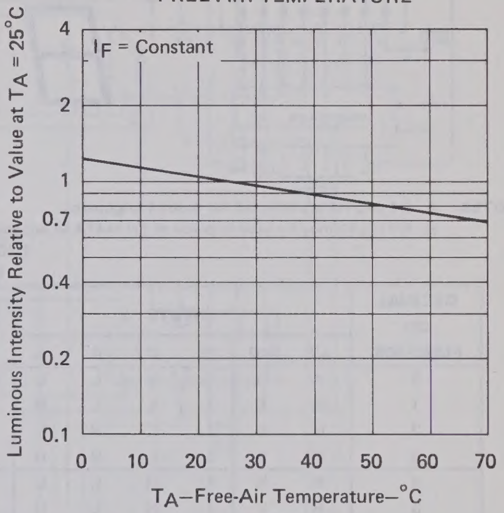


FIGURE 2

RELATIVE LUMINOUS INTENSITY
vs
FORWARD CURRENT

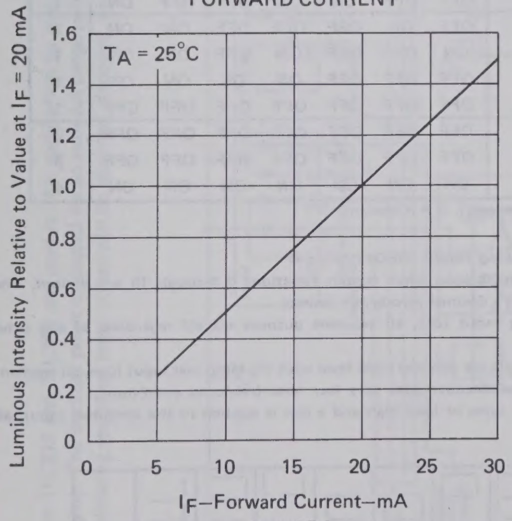


FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

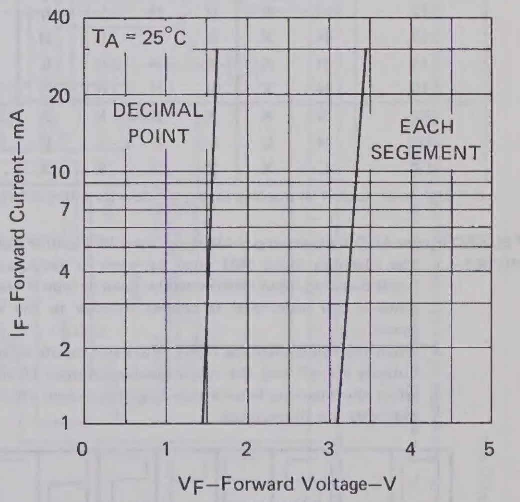
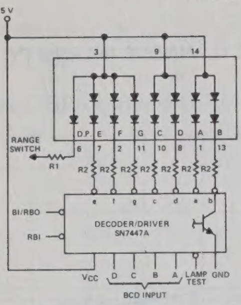
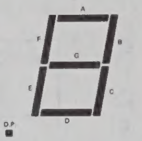


FIGURE 4

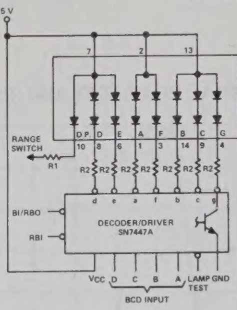
TYPICAL APPLICATION DATA

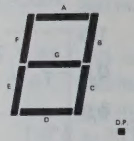
TIL302


5 V
3
9
14
D.P.
E
F
G
C
D
A
B
RANGE SWITCH
6
7
2
11
10
8
1
13
R1
R2
e
f
g
c
d
a
b
BI/RBO
RBI
DECODER/DRIVER
SN7447A
Vcc
D
C
B
A
LAMP TEST
GND
BCD INPUT



TIL303


5 V
7
2
13
D.P.
D
E
A
F
B
C
G
RANGE SWITCH
10
8
6
1
3
14
9
4
R1
R2
d
e
a
f
b
c
g
BI/RBO
RBI
DECODER/DRIVER
SN7447A
Vcc
D
C
B
A
LAMP TEST
GND
BCD INPUT



NOTES: A. R1 and R2 are selected for desired brightness.

B. SN74L47 may be used in place of SN7447A in applications where segment forward current will not exceed 20 mA.

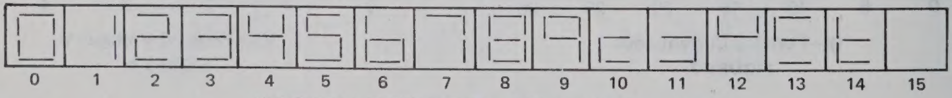
TRUTH TABLE
SN7447A

DECIMAL OR FUNCTION	INPUTS						BI/RBO†	SEGMENTS							NOTE
	LT	RBI	D	C	B	A		a	b	c	d	e	f	g	
0	H	H	L	L	L	L	H	ON	ON	ON	ON	ON	ON	OFF	1
1	H	X	L	L	L	H	H	OFF	ON	ON	OFF	OFF	OFF	OFF	1
2	H	X	L	L	H	L	H	ON	ON	OFF	ON	ON	OFF	ON	1
3	H	X	L	L	H	H	H	ON	ON	ON	ON	OFF	OFF	ON	1
4	H	X	L	H	L	L	H	OFF	ON	ON	OFF	OFF	ON	ON	1
5	H	X	L	H	L	H	H	ON	OFF	ON	ON	OFF	ON	ON	1
6	H	X	L	H	H	L	H	OFF	OFF	ON	ON	ON	ON	ON	1
7	H	X	L	H	H	H	H	ON	ON	ON	OFF	OFF	OFF	OFF	1
8	H	X	H	L	L	L	H	ON	ON	ON	ON	ON	ON	ON	1
9	H	X	H	L	L	H	H	ON	ON	ON	OFF	OFF	ON	ON	1
10	H	X	H	L	H	L	H	OFF	OFF	OFF	ON	ON	OFF	ON	1
11	H	X	H	L	H	H	H	OFF	OFF	ON	ON	OFF	OFF	ON	1
12	H	X	H	H	L	L	H	OFF	ON	OFF	OFF	OFF	ON	ON	1
13	H	X	H	H	L	H	H	ON	OFF	OFF	ON	OFF	ON	ON	1
14	H	X	H	H	H	L	H	OFF	OFF	OFF	ON	ON	ON	ON	1
15	H	X	H	H	H	H	H	OFF	OFF	OFF	OFF	OFF	OFF	OFF	1
BI	X	X	X	X	X	X	L	OFF	OFF	OFF	OFF	OFF	OFF	OFF	2
RBI	H	L	L	L	L	L	L	OFF	OFF	OFF	OFF	OFF	OFF	OFF	3
LT	L	X	X	X	X	X	H	ON	ON	ON	ON	ON	ON	ON	4

H = high level (logic 1 in positive logic), L = low level (logic 0 in positive logic), X = irrelevant.

†BI/RBO is wire-AND logic serving as blanking input (BI) and/or ripple-blanking output (RBO).

NOTES:
1. The blanking input (BI) must be open or held at a high logic level when output functions 0 through 15 are desired. The ripple-blanking input (RBI) must be open or high if blanking of a decimal zero is not desired.
2. When a low logic level is applied directly to the blanking input (BI), all segment outputs are off regardless of any other input.
3. When the ripple-blanking input (RBI) and inputs A, B, C, and D are at a low logic level with the lamp test input high, all segment outputs are off and the ripple-blanking output (RBO) of the decoder goes to a low level (response condition).
4. When the blanking input/ripple blanking output (BI/RBO) is open or held high and a low is applied to the lamp-test input, all segments are illuminated.

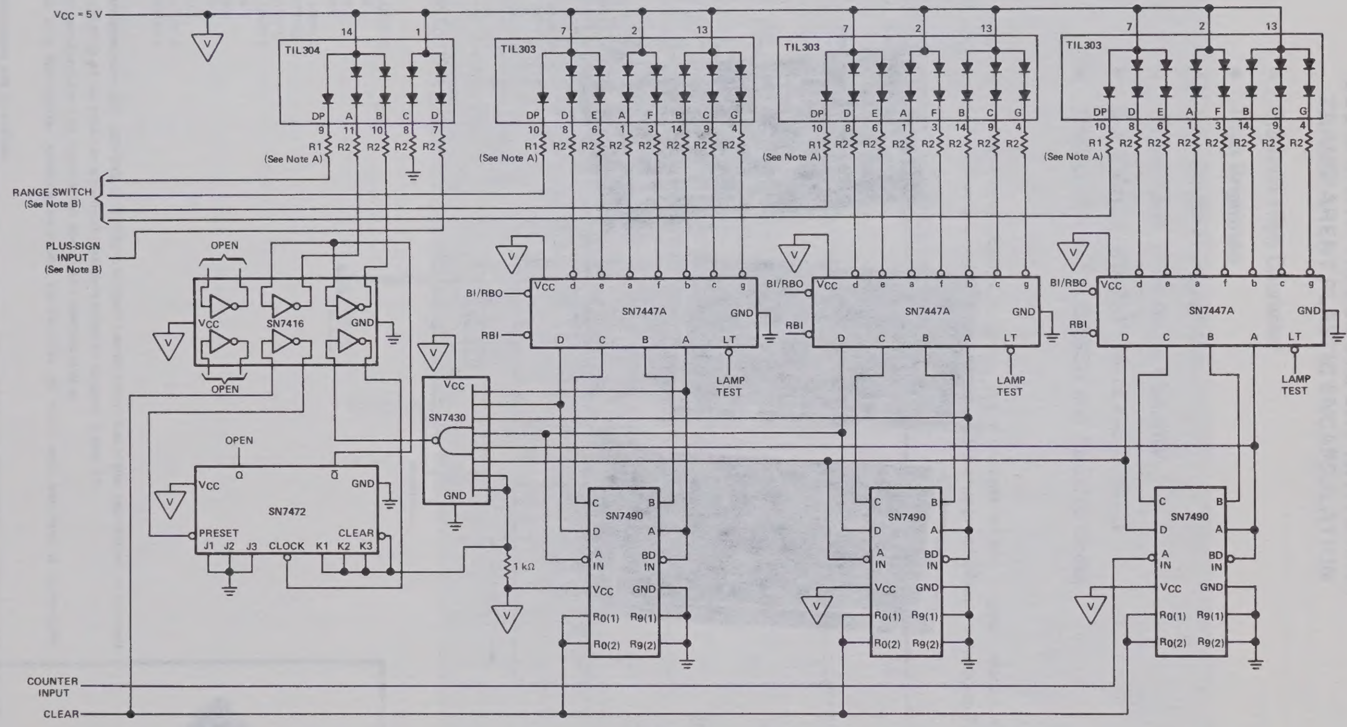

0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

NUMERICAL DESIGNATIONS—RESULTANT DISPLAYS

RECOMMENDED DECODE/DRIVE WITH BCD INPUTS

TYPICAL APPLICATION DATA

The TIL303 and TIL304 are used in this application to make a three-digit display with sign, which is capable of 100% overrange ("1" plus three digits). The decimal point is located via an external range switch. The clear function will blank the overflow digit and reset the three digits to zero. Following resetting, input pulses will be counted, decoded, and displayed.


VCC = 5 V
TIL304
TIL303
TIL303
TIL303
DP
A
B
C
D
E
F
G
R1
R2
(See Note A)
RANGE SWITCH
(See Note B)
PLUS-SIGN INPUT
(See Note B)
OPEN
SN7416
VCC
GND
SN7472
PRESET
CLEAR
J1 J2 J3 CLOCK K1 K2 K3
Q
Q̄
SN7430
SN7447A
BI/RBO
RBI
LT
LAMP TEST
SN7490
A IN
BD IN
R0(1)
R0(2)
R9(1)
R9(2)
1 kΩ
COUNTER INPUT
CLEAR

NOTES: A. R1 and R2 are selected for desired brightness.
B. Grounding of any of these lines will illuminate the associated function.

▽ . . . V_{CC} bus

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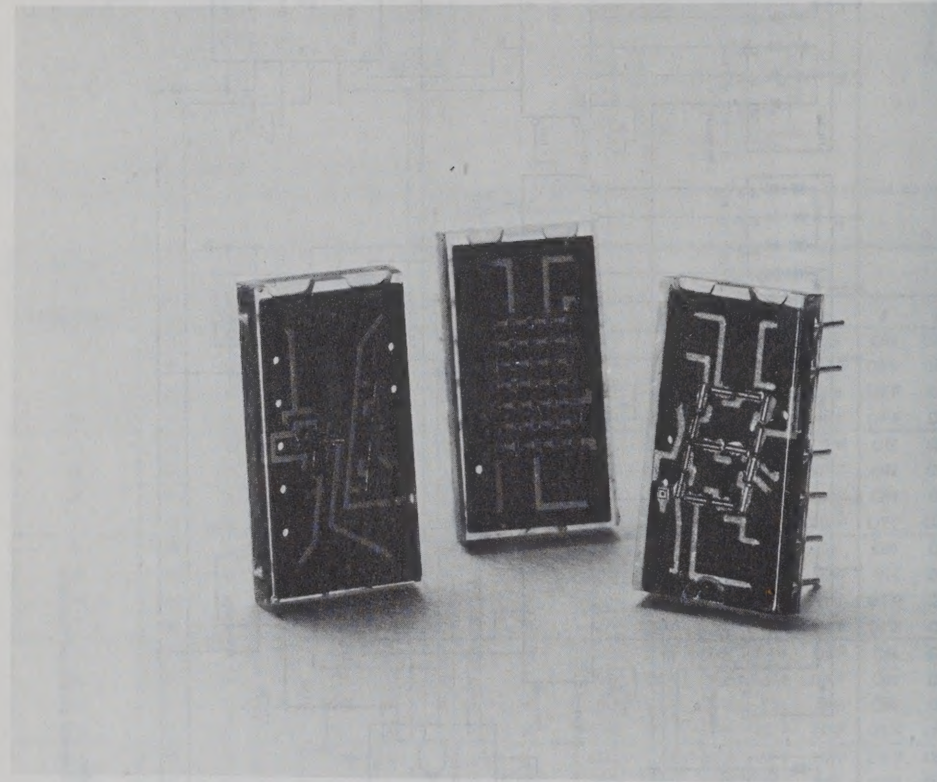


TYPE TIL305
5 X 7 ALPHA-NUMERIC DISPLAY

TYPE TIL305
BULLETIN NO. DL-S 7211495, MAY 1971
REVISED MARCH 1972

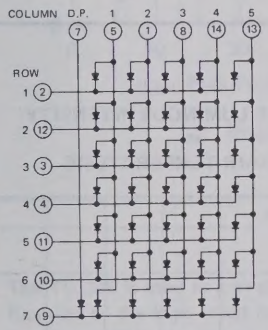
SOLID-STATE VISIBLE DISPLAY WITH CLEAR TRANSPARENT PLASTIC ENCAPSULATION

- 0.3-Inch-High Character
- High Brightness
- Low Power Requirements
- Single-Plane, Wide-Angle Visibility
- 5 X 7 Array with X-Y Select and Decimal
- Compatable with USASCII and EBCDIC Codes

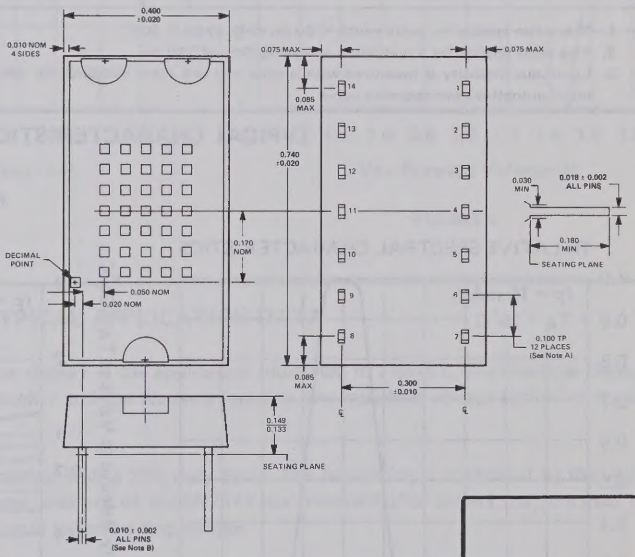
mechanical data

The displays are mounted on lead-frame assemblies which are then cast within a clear, electrically nonconductive, transparent plastic compound. Displays are also available in a red transparent plastic compound.

Multiple displays may be mounted on 0.450-inch centers.


COLUMN
D.P.
1
2
3
4
5
⑦
⑤
①
⑧
⑭
⑬
ROW
1 ②
2 ⑫
3 ③
4 ④
5 ⑪
6 ⑩
7 ⑨

TOP VIEW ORIENTATION


0.400 ±0.020
0.010 NOM 4 SIDES
0.075 MAX
0.075 MAX
0.085 MAX
0.740 ±0.020
14
13
12
11
10
9
8
1
2
3
4
5
6
7
0.030 MIN
0.018 ± 0.002 ALL PINS
0.180 MIN
SEATING PLANE
0.170 NOM
DECIMAL POINT
0.050 NOM
0.020 NOM
0.100 TP 12 PLACES (See Note A)
0.085 MAX
0.300 ±0.010
℄
℄
0.149
0.133
SEATING PLANE
0.010 ± 0.002 ALL PINS (See Note B)

PIN 1	COLUMN 2
PIN 2	ROW 1
PIN 3	ROW 3
PIN 4	ROW 4
PIN 5	COLUMN 1
PIN 6	OMITTED
PIN 7	DECIMAL
PIN 8	COLUMN 3
PIN 9	ROW 7
PIN 10	ROW 6
PIN 11	ROW 5
PIN 12	ROW 2
PIN 13	COLUMN 5
PIN 14	COLUMN 4

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within ±0.010 of its true longitudinal position relative to pins 4 and 11.
B. Lead dimensions are not controlled above the seating plane.
C. Vertical and horizontal spacing between centerlines of rows and columns is nominally 0.050.
D. All dimensions are in inches.

TYPE TIL305
5 X 7 ALPHA-NUMERIC DISPLAY

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature	3 V
Peak Forward Current, Each Diode (See Note 1)	100 mA
Average Forward Current (See Note 2):	
Each Diode	20 mA
Total	400 mA
Operating Free-Air Temperature Range	0° to 70°C
Storage Temperature Range	−55°C to 100°C

operating characteristics of each diode at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_v	Luminous Intensity (See Note 3)	I_F = 10 mA	40	110		µcd
λp	Wavelength at Peak Emission		640	660	680	nm
B	Spectral Bandwidth between Half-Power Points			20		nm
V_F	Static Forward Voltage		1.5	1.65	2	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 10 mA, T_A = 0°C to 70°C		−1.4		mV/°C
I_R	Static Reverse Current	V_R = 3 V			100	µA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		80		pF

NOTES: 1. This value applies for pulse width ≤ 50 µs, duty cycle ≤ 20%.

2. This value applies for a maximum averaging time of 250 µs.

3. Luminous intensity is measured with a solar cell and filter combination which approximates the CIE (International Commission on Illumination) eye-response curve.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

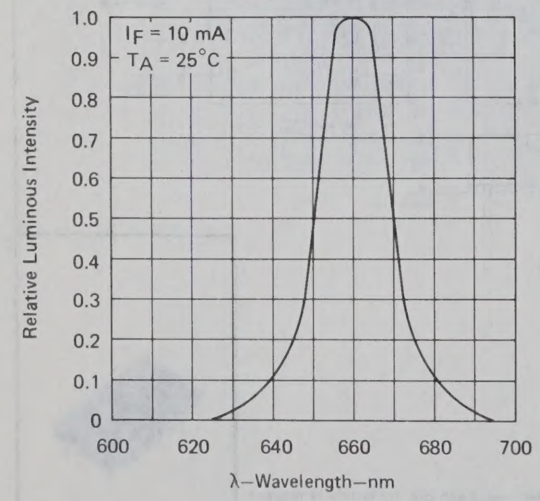


FIGURE 1

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

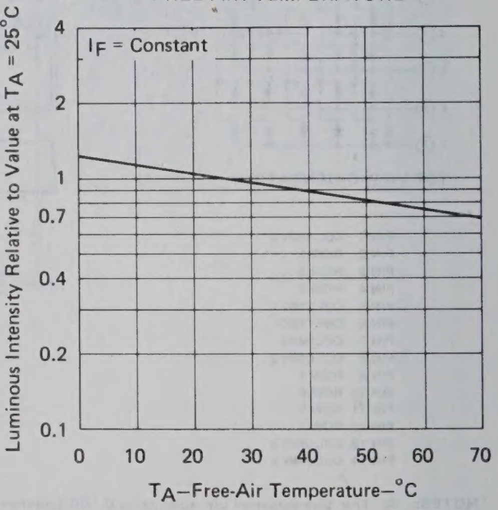


FIGURE 2

TYPICAL CHARACTERISTICS

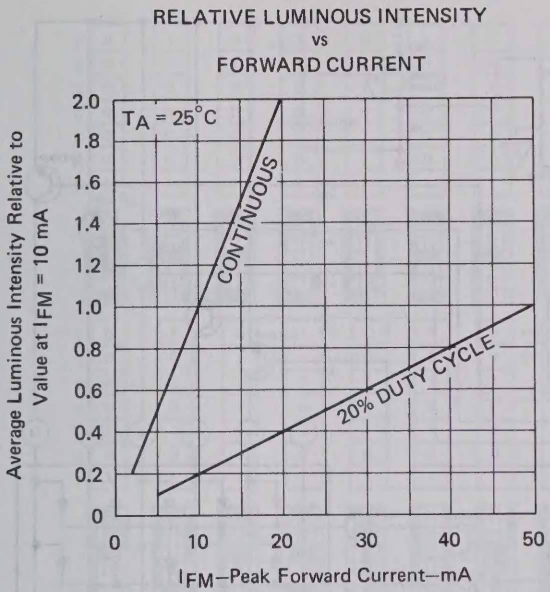


FIGURE 3

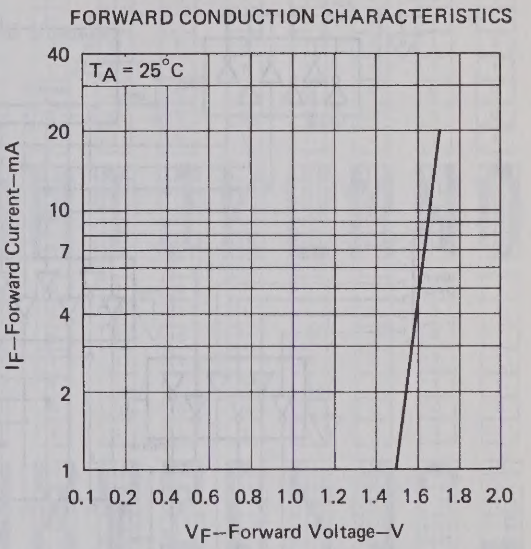


FIGURE 4

TYPICAL APPLICATION DATA

The TIL305 is used as a single character display in the application illustrated in Figure 5. The character displayed is a function of the logic input lines 1 through 7 and the blanking input. A low-logic-level voltage applied to the blanking input will inhibit the display.

The five columns of the TIL305 are scanned with a 20% duty cycle. The sequencing is controlled by the unijunction transistor oscillator, SN7496 shift register, and one of the SN7416 hex inverter/buffer drivers that are used to invert and feed the outputs back to the serial input to form a ring counter.

The outputs of the ring counter are used to drive the column drivers (A5T2907's) and the column select inputs of the read-only memory after being inverted through another SN7416.

The logic inputs 1 through 7 are inverted with another SN7416 to make the inputs compatible with positive logic and Series 54/74 levels.

If the coding at the inputs 1 through 7 is USASCII, a TMS4103JC or TMS4103NC read-only memory may be used to display the alpha-numeric characters per Figure 6. If the coding is EBCDIC, then a TMS4179JC or TMS4179NC will display the alpha-numeric characters per Figure 7. The TMS4103 and TMS4179 are pin-for-pin replacements in this circuit. Other codes may be used with a custom TMS4100 read-only memory.

TYPICAL APPLICATION DATA

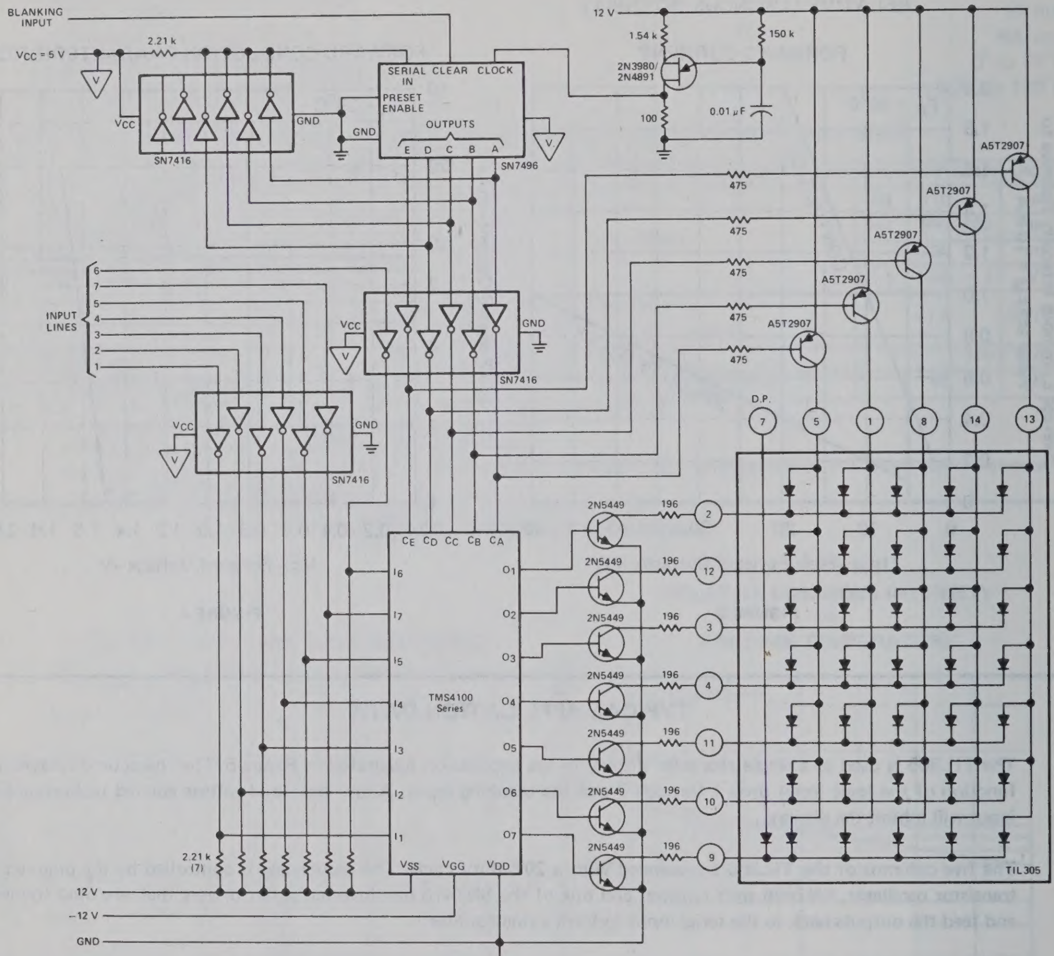

BLANKING INPUT
VCC = 5 V
2.21 k
VCC
SN7416
GND
SERIAL IN
CLEAR
CLOCK
PRESET ENABLE
OUTPUTS
E D C B A
SN7496
V
12 V
1.54 k
150 k
2N3980/ 2N4891
100
0.01 µF
475
475
475
475
475
A5T2907
A5T2907
A5T2907
A5T2907
A5T2907
INPUT LINES
6
7
5
4
3
2
1
VCC
GND
SN7416
VCC
GND
SN7416
D.P.
7
5
1
8
14
13
CE CD CC CB CA
I6
I7
I5
I4
I3
I2
I1
O1
O2
O3
O4
O5
O6
O7
TMS4100 Series
VSS VGG VDD
2N5449
196
2
12
3
4
11
10
9
TIL305
2.21 k (7)
12 V
−12 V
GND

FIGURE 5

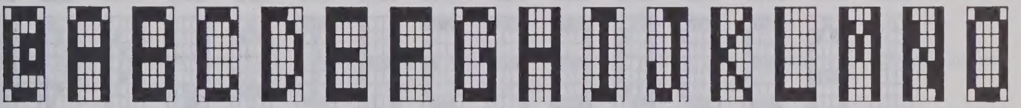
Resistor values are in ohms.

V . . . VCC bus.

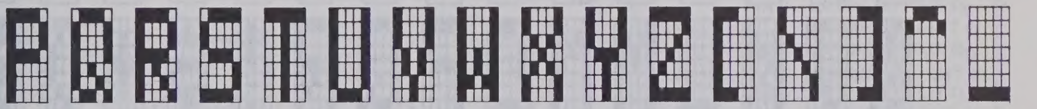
TYPICAL APPLICATION DATA

RESULTANT DISPLAYS USING TMS4103JC OR TMS4103NC WITH USASCII CODED INPUTS

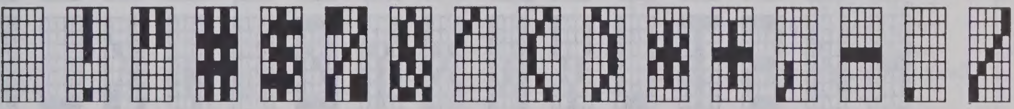
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



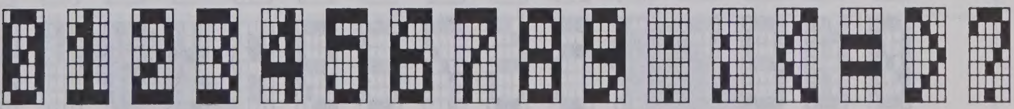
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

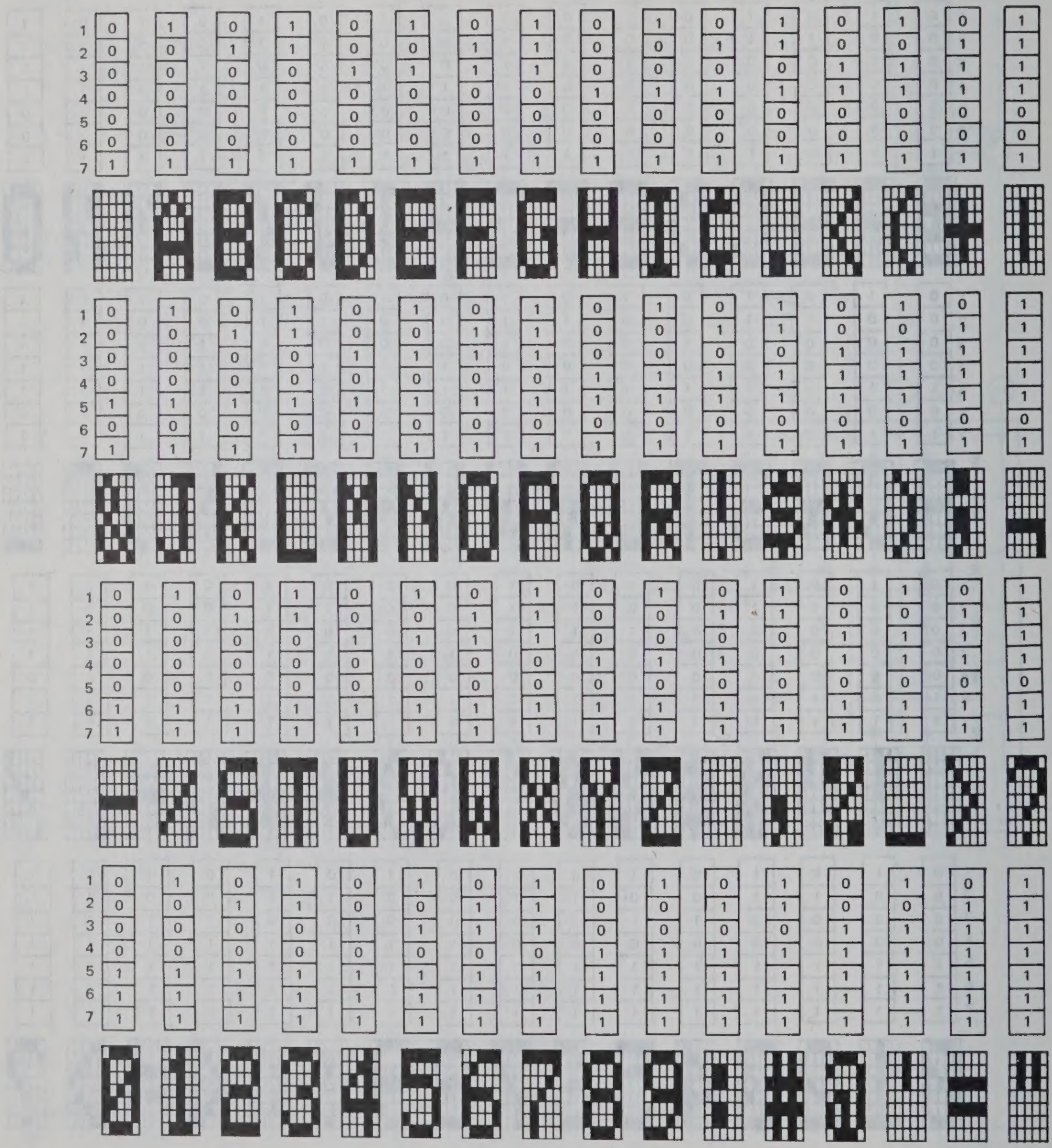


positive logic: 1 = H = 2 V to 5.5 V
0 = L = 0 V to 0.8 V

FIGURE 6

TYPICAL APPLICATION DATA

RESULTANT DISPLAYS USING TMS4179JC OR TMS4179NC WITH EBCDIC CODED INPUTS



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

positive logic: 1 = H = 2 V to 5.5 V
0 = L = 0 V to 0.8 V

FIGURE 7

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TYPES TIL306, TIL307
NUMERIC DISPLAYS WITH LOGIC

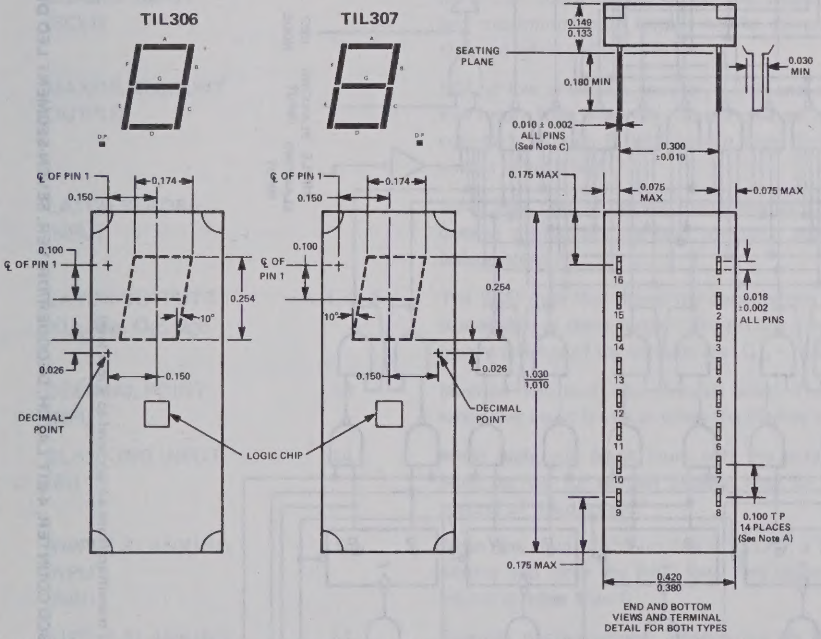
TYPES TIL306, TIL307
BULLETIN NO. DL-S 7211551, MARCH 1972
REPLACES BULLETIN NO. DL-S 711551, SEPTEMBER 1971

SOLID-STATE VISIBLE DISPLAYS WITH INTEGRAL TTL MSI CIRCUIT CHIP FOR USE IN ALL SYSTEMS WHERE THE DATA TO BE DISPLAYED IS THE PULSE COUNT

- 0.270 Inch High Character
- High Brightness
- TIL306 Has Left Decimal
- TIL307 Has Right Decimal
- Easy System Interface
- Single-Plane Wide-Angle Visibility
- Internal TTL MSI Chip and Counter, Latch, Decoder, and Driver
- Constant-Current Drive for Light-Emitting Diodes

mechanical data

The displays are mounted on lead-frame assemblies which are then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.


TIL306
TIL307
A
B
C
D
E
F
G
DP
℄ OF PIN 1
0.174
0.150
0.100
0.254
10°
0.026
0.150
DECIMAL POINT
LOGIC CHIP
℄ OF PIN 1
SEATING PLANE
0.149
0.133
0.180 MIN
0.030 MIN
0.010 ± 0.002 ALL PINS (See Note C)
0.300 ±0.010
0.175 MAX
0.075 MAX
0.075 MAX
1.030
1.010
0.018 ±0.002 ALL PINS
0.100 T P 14 PLACES (See Note A)
0.175 MAX
0.420
0.380
16 15 14 13 12 11 10 9
1 2 3 4 5 6 7 8
END AND BOTTOM VIEWS AND TERMINAL DETAIL FOR BOTH TYPES

PIN ASSIGNMENTS FOR BOTH TYPES

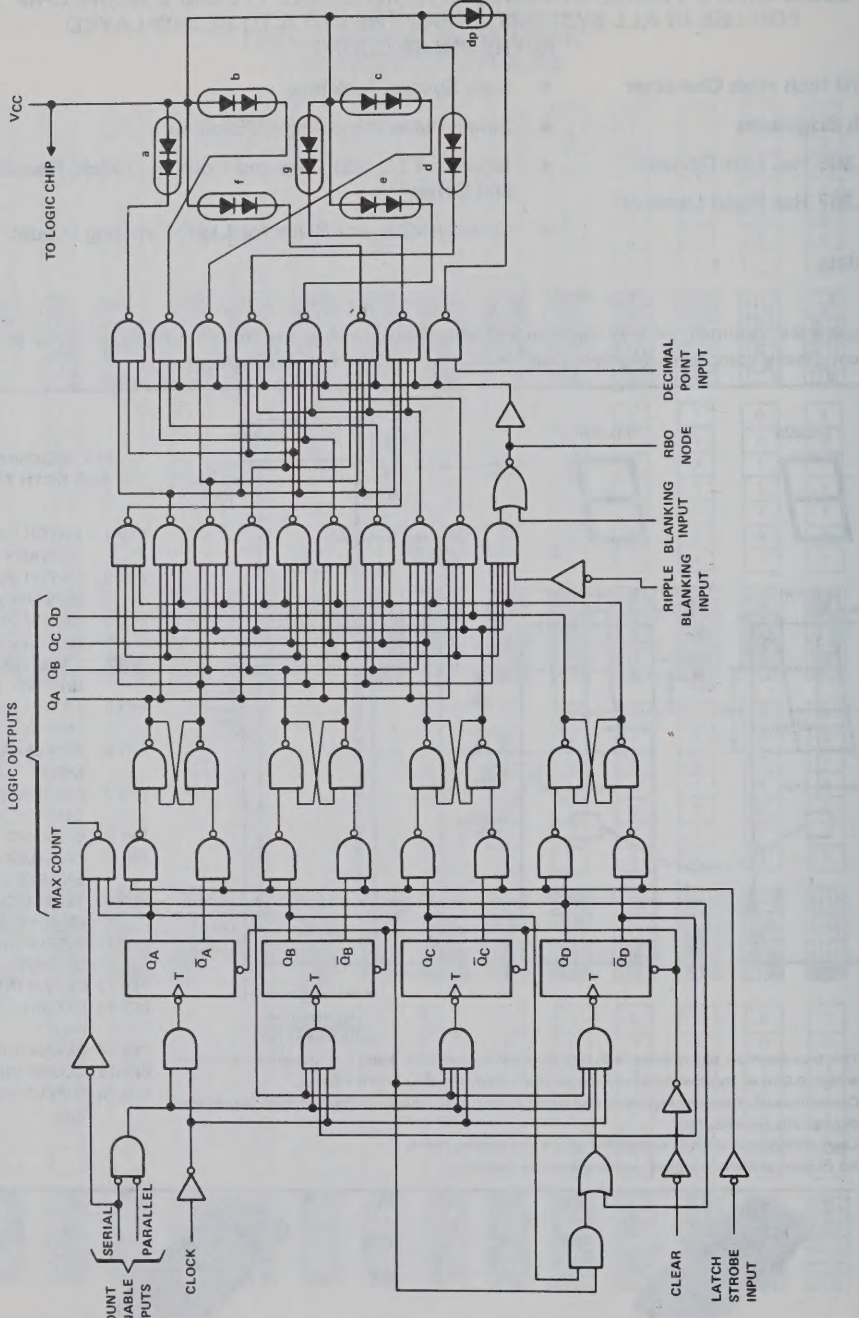
PIN 1	LATCH OUTPUT Q_B (BINARY WEIGHT 2)
PIN 2	LATCH OUTPUT Q_C (BINARY WEIGHT 4)
PIN 3	LATCH OUTPUT Q_D (BINARY WEIGHT 8)
PIN 4	LATCH OUTPUT Q_A (BINARY WEIGHT 1)
PIN 5	LATCH STROBE INPUT
PIN 6	RIPPLE-BLANKING INPUT
PIN 7	MAXIMUM-COUNT OUTPUT
PIN 8	GROUND
PIN 9	PARALLEL COUNT ENABLE INPUT
PIN 10	SERIAL COUNT ENABLE INPUT
PIN 11	RIPPLE-BLANKING OUTPUT
PIN 12	CLEAR INPUT
PIN 13	DECIMAL POINT INPUT
PIN 14	BLANKING INPUT
PIN 15	CLOCK INPUT
PIN 16	SUPPLY VOLTAGE, V_{CC}

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 1 and 16.
B. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
C. Lead dimensions are not controlled above the seating plane.
D. All dimensions are in inches unless otherwise specified.

TIL306

TIL307

functional block diagram


VCC
TO LOGIC CHIP
a
b
c
d
e
f
g
dp
DECIMAL POINT INPUT
RBO NODE
BLANKING INPUT
RIPPLE BLANKING INPUT
LOGIC OUTPUTS
Q_A Q_B Q_C Q_D
MAX COUNT
Q_A $\bar{Q}_A$
Q_B $\bar{Q}_B$
Q_C $\bar{Q}_C$
Q_D $\bar{Q}_D$
T
COUNT ENABLE INPUTS
SERIAL
PARALLEL
CLOCK
CLEAR
LATCH STROBE INPUT

. . . Dynamic input activated by a transition from a high level to a low level

SYNCHRONOUS BCD COUNTER, 4-BIT LATCH, DECODER/DRIVER, SEVEN-SEGMENT LED DISPLAY WITH DECIMAL POINT

description

These internally-driven seven-segment light-emitting-diode (LED) displays contain a BCD counter, a four-bit latch, and a decoder/LED driver in a single 16-pin package. A description of the functions of the inputs and outputs of these devices follows:

FUNCTION	PIN NO.	DESCRIPTION
CLEAR INPUT	12	When low, resets and holds counter at 0. Must be high for normal counting.
CLOCK INPUT	15	Each positive-going transition will increment the counter provided that the circuit is in the normal counting mode (serial and parallel count enable inputs low, clear input high).
PARALLEL COUNT ENABLE INPUT (PCEI)	9	Must be low for normal counting mode. When high, counter will be inhibited. Logic level must not be changed when the clock is low.
SERIAL COUNT ENABLE INPUT (SCEI)	10	Must be low for normal counting mode, also must be low to enable maximum count output to go low. When high, counter will be inhibited and maximum count output will be driven high. Logic level must not be changed when the clock is low.
MAXIMUM COUNT OUTPUT	7	Will go low when the counter is at 9 and serial count enable input is low. Will return high when the counter changes to 0 and will remain high during counts 1 through 8. Will remain high (inhibited) as long as serial count enable input is high.
LATCH STROBE INPUT	5	When low, data in latches follow the data in the counter. When high, the data in the latches are held constant, and the counter may be operated independently.
LATCH OUTPUTS (Q_A, Q_B, Q_C, Q_D)	4, 1, 2, 3	The BCD data that drives the decoder can be stored in the 4-bit latch and is available at these outputs for driving other logic and/or processors. The binary weights of the outputs are: $Q_A = 1$, $Q_B = 2$, $Q_C = 4$, $Q_D = 8$.
DECIMAL POINT INPUT	13	Must be high to display decimal point. The decimal point is not displayed when this input is low or when the display is blanked.
BLANKING INPUT (BI)	14	When high, will blank (turn off) the entire display and force RBO low. Must be low for normal display. May be pulsed to implement intensity control of the display.
RIPPLE-BLANKING INPUT (RBI)	6	When the data in the latches is BCD 0, a low input will blank the entire display and force the RBO low. This input has no effect if the data in the latches is other than 0.
RIPPLE-BLANKING OUTPUT (RBO)	11	Supplies ripple-blanking information for the ripple-blanking input of the next decade. Provides a low if BI is high, or if RBI is low and the data in the latches is BCD 0; otherwise, this output is high. This pin has a resistive pull-up circuit suitable for performing a wire-AND function with any open-collector output. Whenever this pin is low the entire display will be blanked; therefore, this pin may be used as an active-low blanking input.

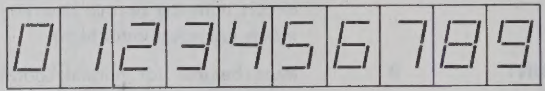
The TTL MSI circuits contain the equivalent of 86 gates on a single chip. Logic inputs and outputs are completely TTL/DTL compatible. The buffered inputs are implemented with relatively large resistors in series with the bases of the input transistors to lower drive-current requirements to one-half of that required for a standard Series 54/74 TTL input. The serial-carry input, actually two internal loads, is rated as one standard series 54/74 load.

description (continued)

The logic outputs, except RBO, are active pull-up, and the latch outputs Q_A, Q_B, Q_C, and Q_D are each capable of driving three standard Series 54/74 loads at a low logic level or six loads at a high logic level while the maximum-count output is capable of driving seven Series 54/74 loads at a low logic level or 14 loads at a high logic level. The RBO node with passive pull-up serves as a ripple-blanking output with the capability to drive three Series 54/74 loads.

The LED driver outputs are designed specifically to maintain a relatively constant on-level current of approximately 15 milliamperes through LED segments "a" through "g" and seven milliamperes through the decimal point LED. All inputs are diode-clamped to minimize transmission-line effects, thereby simplifying system design. Maximum clock frequency is typically 18 megahertz and power dissipation is typically 850 milliwatts with all segments on.

The display format is as follows:



The displays may be interconnected to produce an n-digit display with the following features:

- Ripple-blanking input and output for blanking leading or trailing zeroes
- Floating-decimal-point logic capability
- Overriding blanking for suppressing entire display or pulse-modulation of LED brightness
- Dual count-enable inputs for parallel look-ahead and serial ripple logic to build high-speed fully synchronous, multidigit counter systems with no external logic, minimizing total propagation delay from the clock to the last latch output
- Provision for ripple-count cascading between packages
- Positive-edge-triggered synchronous BCD counter
- Parallel BCD data outputs available to drive logic processors or remote slaved displays simultaneously with data being displayed
- Latch strobe input allows counter to operate while a previous data point is displayed
- Reset-to-zero capability with clear input.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply Voltage, V_{CC} (See Note 1): Continuous	5.5 V
Nonrepetitive Peak, $t_w \leqslant 100$ ms	7 V
Input Voltage (See Note 1)	5.5 V
Operating Free-Air Temperature Range	0°C to 70°C
Storage Temperature Range	–55°C to 100°C

NOTE 1: Voltage are with respect to network ground terminal.

recommended operating conditions

			MIN	NOM	MAX	UNIT
Supply Voltage, V_{CC}			4.75	5	5.25	V
Normalized Fan-Out from Each Output, N (to Series 54 Integrated Circuits)	Low Logic Level	Q_A, Q_B, Q_C, Q_D, RBO			3	
		Maximum Count			7	
	High Logic Level	RBO			3	
		Q_A Q_B, Q_C, Q_D			6	
		Maximum Count			14	
Clock Pulse Width, $t_{w(clock)}$		High Logic Level	25			ns
		Low Logic Level	55			
Clear Pulse Width, $t_{w(clear)}$			25			ns
Latch Strobe Pulse Width, $t_{w(latch\ strobe)}$			45			ns
Setup Time, t_{setup} (See Note 2)		Serial Carry and Parallel Carry	30			ns
		Clear Inactive State	30			

NOTE 2: Setup time is the interval immediately preceding the positive-going edge of the clock pulse during which interval the data to be recognized must be maintained at the input to ensure its recognition.

operating characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
I_v	Luminous Intensity (See Note 3)	Figure 8	$V_{CC} = 5$ V	700	1200		μcd
		Decimal Point		40	70		μcd
λ_P	Wavelength at Peak Emission		$V_{CC} = 5$ V, See Note 4	640	660	680	nm
B	Spectral Bandwidth Between Half-Power Points		$V_{CC} = 5$ V, See Note 4		20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_I	Input Clamp Voltage		$V_{CC} = 4.75$ V, $I_I = -12$ mA			−1.5	V
V_{OH}	High-Level Output Voltage	RBO	$V_{CC} = 4.75$ V, $I_{OH} = -120$ μA	2.4			V
		Q_A, Q_B, Q_C, Q_D	$V_{CC} = 4.75$ V, $I_{OH} = -240$ μA				
		Maximum Count	$V_{CC} = 4.75$ V, $I_{OH} = -560$ μA				
V_{OL}	Low-Level Output Voltage	Q_A, Q_B, Q_C, Q_D, RBO	$V_{CC} = 4.75$ V, $I_{OL} = 4.8$ mA			0.4	V
		Maximum Count	$V_{CC} = 4.75$ V, $I_{OL} = 11.2$ mA				
I_I	Input Current at Maximum Input Voltage		$V_{CC} = 5.25$ V, $V_I = 5.5$ V			1	mA
I_{IH}	High-Level Input Current	Serial Carry	$V_{CC} = 5.25$ V, $V_I = 2.4$ V			40	μA
		RBO Node		−0.12	−0.5		mA
		Other Inputs				20	μA
I_{IL}	Low-Level Input Current	Serial Carry	$V_{CC} = 5.25$ V, $V_I = 0.4$ V			−1.6	mA
		RBO Node			−1.5	−2.4	
		Other Inputs				−0.8	
I_{OS}	Short-Circuit Output Current	Q_A, Q_B, Q_C, Q_D	$V_{CC} = 5.25$ V	−9		−27.5	mA
		Maximum Count		−15		−55	
I_{CC}	Supply Current		$V_{CC} = 5.25$ V, See Note 4		170	250	mA

‡All typical values are at $V_{CC} = 5$ V

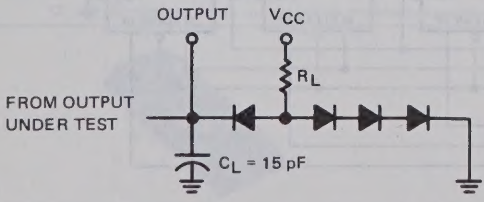
NOTES: 3. Luminous intensity is measured with a solar cell and filter combination which approximates the CIE (International Commision on Illumination) eye-response curve.

4. These parameters are measured with all LED segments and the decimal point on.

switching characteristics, $V_{CC} = 5$ V, $T_A = 25°$C

PARAMETER§	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{max}				12	18		MHz
t_{PLH}	Serial Look-Ahead	Maximum Count	$C_L = 15$ pF, $R_L = 560\ \Omega$, See Figure 1		12		ns
t_{PHL}					23		
t_{PLH}	Clock	Maximum Count			26		ns
t_{PHL}					29		
t_{PLH}	Clock	Q_A, Q_B, Q_C, Q_D	$C_L = 15$ pF, $R_L = 1.2\ k\Omega$, See Figure 1		28		ns
t_{PHL}					38		
t_{PHL}	Clear	Q_A, Q_B, Q_C, Q_D			57		ns

§f_{max} ≡ Maximum clock frequency
t_{PLH} ≡ Propagation delay time, low-to-high-level output
t_{PHL} ≡ Propagation delay time, high-to-low-level output



NOTES: A. C_L includes probe and jig capacitance.
B. All diodes are 1N3064.

LOAD CIRCUIT—FIGURE 1

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

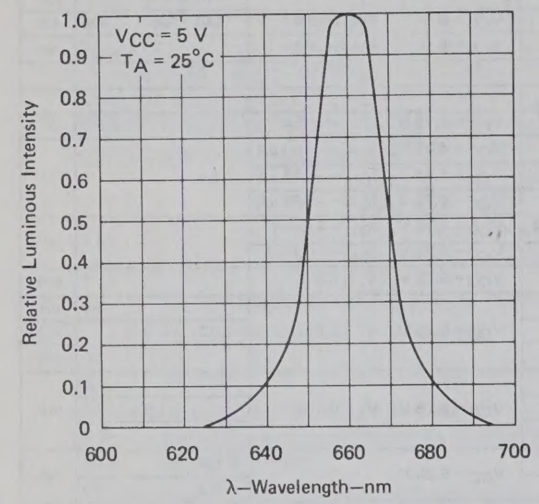


FIGURE 2

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

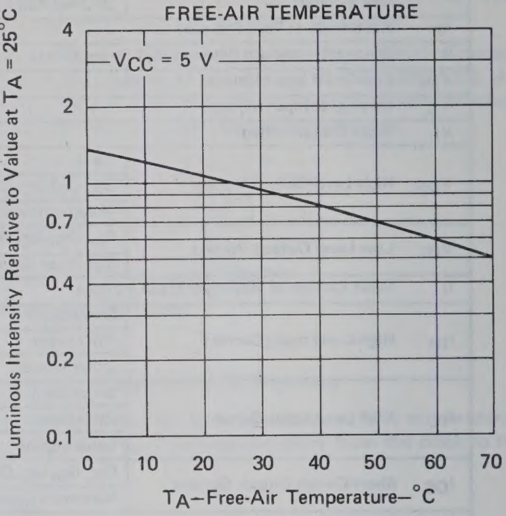
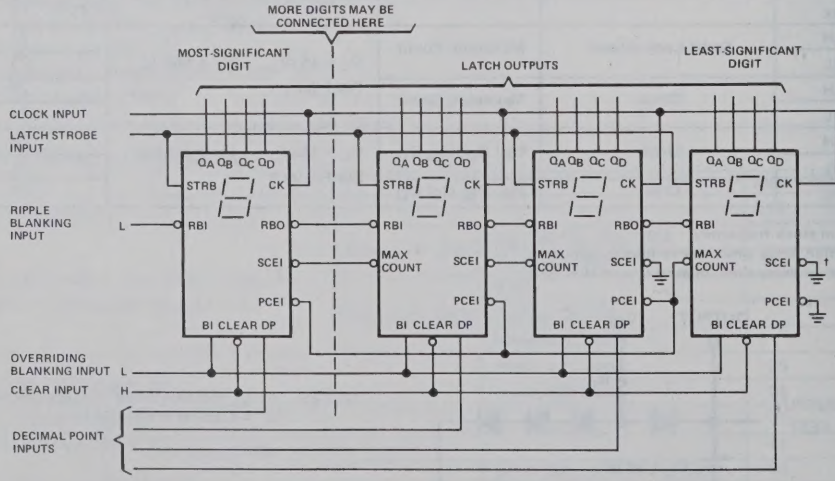


FIGURE 3

TYPICAL APPLICATION DATA

This application demonstrates how the displays may be cascaded for N-bit display applications. It features:

Synchronous, look-ahead counting
Ripple blanking for leading zeros
Overriding blanking for total suppression or intensity modulation of display
Direct parallel clear
Latch strobe permits counter to acquire data for the next display while viewing current display.


MORE DIGITS MAY BE CONNECTED HERE
MOST-SIGNIFICANT DIGIT
LATCH OUTPUTS
LEAST-SIGNIFICANT DIGIT
CLOCK INPUT
LATCH STROBE INPUT
RIPPLE BLANKING INPUT
L
QA QB QC QD
STRB
CK
RBI
RBO
SCEI
PCEI
MAX COUNT
BI CLEAR DP
†
OVERRIDING BLANKING INPUT L
CLEAR INPUT H
DECIMAL POINT INPUTS

---

† The serial carry input of the least-significant digit is normally grounded; however, it may be used as a count-enable control for the entire counter (high to disable, low to count) provided the logic level on this pin is not changed while the clock line is low or false counting may result.

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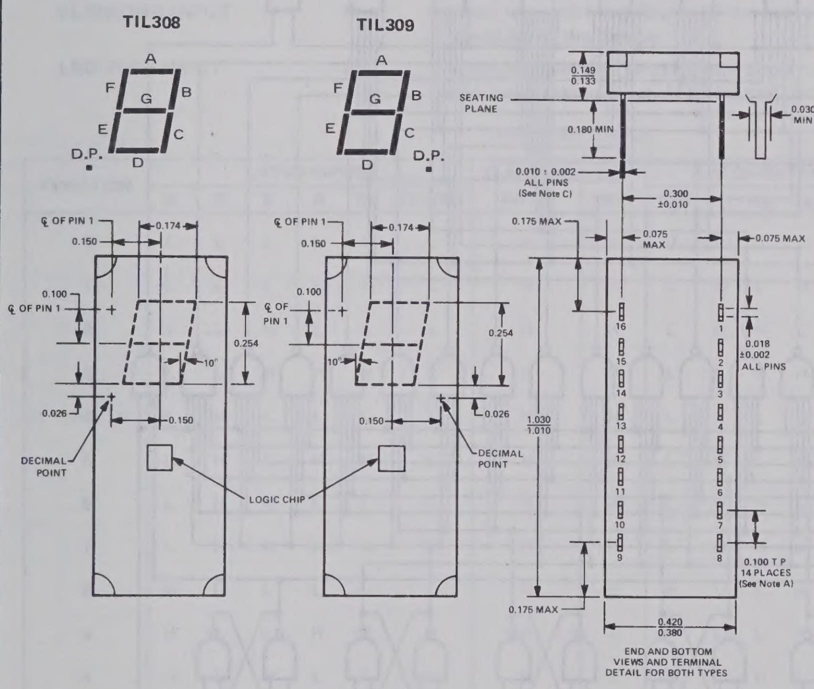
SOLID-STATE VISIBLE DISPLAYS WITH INTEGRAL TTL MSI CIRCUIT CHIP FOR USE IN ALL SYSTEMS REQUIRING A DISPLAY OF BCD DATA

- 0.270-Inch-High Character
- High Brightness
- TIL308 Has Left Decimal
- TIL309 Has Right Decimal
- Easy System Interface
- Single-Plane Wide-Angle Visibility
- Internal TTL MSI Chip with Latch, Decoder, and Driver
- Constant-Current Drive for Light-Emitting Diodes

mechanical data

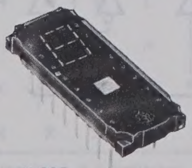
The display and TTL MSI chip are mounted on a lead-frame assembly which is then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.

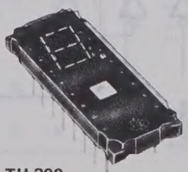

TIL308
TIL309
A
B
C
D
E
F
G
D.P.
℄ OF PIN 1
0.174
0.150
0.100
0.254
10°
0.026
DECIMAL POINT
LOGIC CHIP
0.149
0.133
SEATING PLANE
0.180 MIN
0.030 MIN
0.010 ± 0.002 ALL PINS (See Note C)
0.300 ±0.010
0.175 MAX
0.075 MAX
0.075 MAX
0.018 ±0.002 ALL PINS
1.030
1.010
0.100 T P 14 PLACES (See Note A)
0.420
0.380
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
END AND BOTTOM VIEWS AND TERMINAL DETAIL FOR BOTH TYPES

PIN ASSIGNMENTS FOR BOTH TYPES

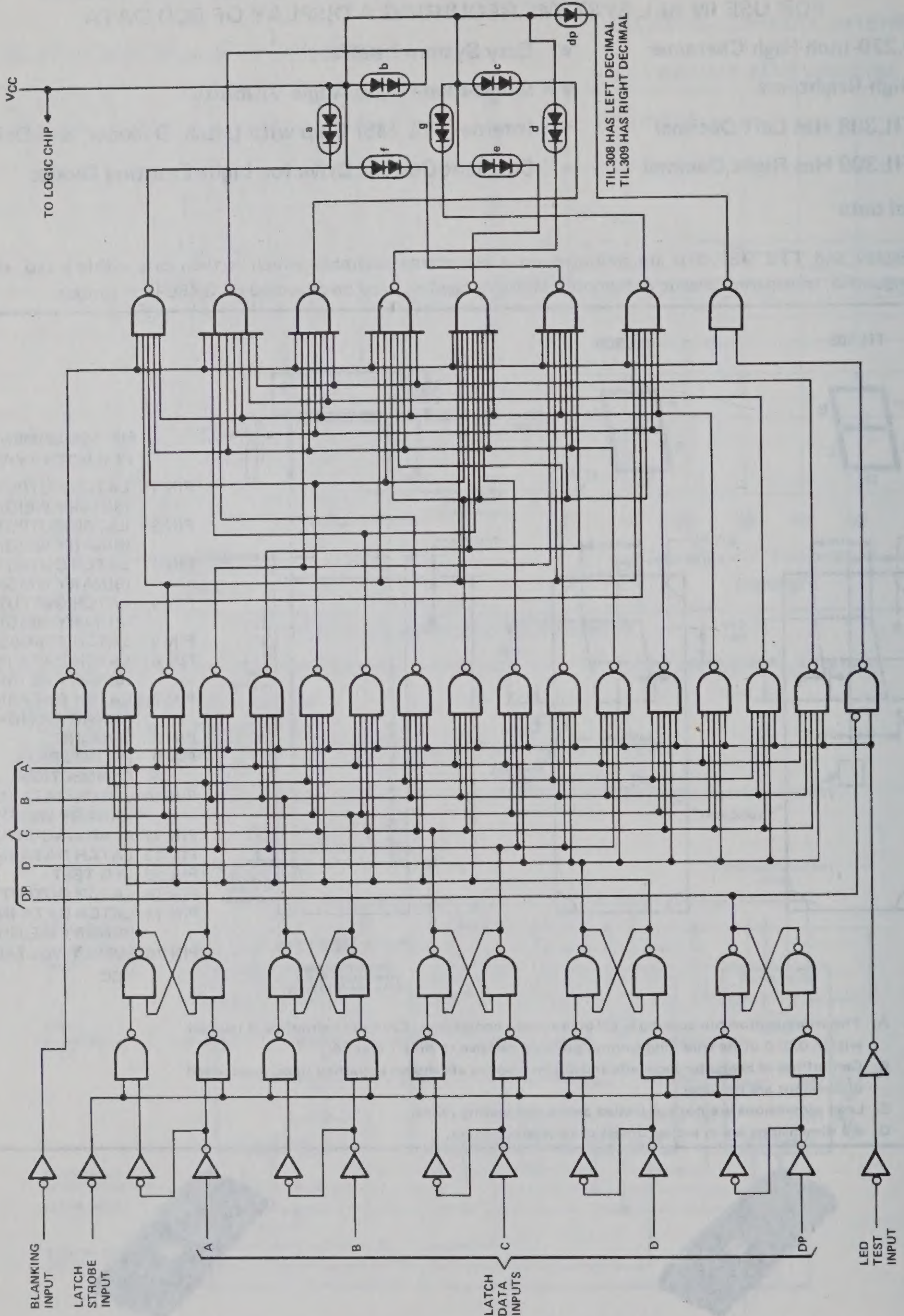
PIN 1	LATCH OUTPUT Q_B (BINARY WEIGHT 2)
PIN 2	LATCH OUTPUT Q_C (BINARY WEIGHT 4)
PIN 3	LATCH OUTPUT Q_D (BINARY WEIGHT 8)
PIN 4	LATCH OUTPUT Q_A (BINARY WEIGHT 1)
PIN 5	LATCH STROBE INPUT
PIN 6	LATCH DATA INPUT C (BINARY WEIGHT 4)
PIN 7	LATCH DATA INPUT D (BINARY WEIGHT 8)
PIN 8	GROUND
PIN 9	NO INTERNAL CONNECTION
PIN 10	LATCH DATA INPUT B (BINARY WEIGHT 2)
PIN 11	BLANKING INPUT
PIN 12	LATCH DATA INPUT DP
PIN 13	LED TEST
PIN 14	LATCH OUTPUT DP
PIN 15	LATCH DATA INPUT A (BINARY WEIGHT 1)
PIN 16	SUPPLY VOLTAGE, V_{CC}

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal poistion relative to pins 1 and 16.
B. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
C. Lead dimensions are not controlled above the seating plane.
D. All dimensions are in inches unless otherwise specified.


TIL308


TIL309

functional block diagram


VCC
TO LOGIC CHIP
a
b
c
d
e
f
g
dp
TIL308 HAS LEFT DECIMAL
TIL309 HAS RIGHT DECIMAL
LATCH OUTPUTS
A
B
C
D
DP
BLANKING INPUT
LATCH STROBE INPUT
A
B
C
D
DP
LATCH DATA INPUTS
LED TEST INPUT

description

These internally-driven seven-segment light-emitting-diode (LED) displays contain a five-bit latch and a decoder/LED driver in a single 16-pin package. A description of the functions of the inputs and outputs of these devices follows:

FUNCTION	PIN NO.	DESCRIPTION
LATCH STROBE INPUT	5	When low, the data in the latches follow the data on the latch inputs. When high, the data in the latches are held constant and are unaffected by new data on the latch inputs.
LATCH DATA INPUTS A, B, C, D, DP	15, 10, 6, 7, 12	Data on these inputs are entered into the latches under the control of the latch strobe input. The binary weights of the inputs are: A = 1, B = 2, C = 4, D = 8. DP is decimal point latch data input.
LATCH OUTPUTS Q_A, Q_B, Q_C, Q_D, Q_{DP}	4, 1, 2, 3, 14	The BCD data that drives the decoder is stored in the five latches and is available at these outputs. The binary weights of the outputs are: $Q_A = 1$, $Q_B = 2$, $Q_C = 4$, $Q_D = 8$. Q_{DP} is decimal point latch output.
BLANKING INPUT	11	When low, will blank (turn off) the entire display. Must be high for normal operation of the display.
LED TEST INPUT	13	When low, will turn on the entire display, overriding the data in the latches and the blanking input. Must be high for normal operation of the display.

FUNCTION TABLE

FUNCTION	LATCH INPUTS						BLANKING	LED	LATCH OUTPUTS					DISPLAY	
	D	C	B	A	DP	STROBE	INPUT	TEST	Q_D	Q_C	Q_B	Q_A	Q_{DP}	TIL308	TIL309
0	L	L	L	L	L	L	H	H	L	L	L	L	L	0	0
1	L	L	L	H	H	L	H	H	L	L	L	H	H	.1	1.
2	L	L	H	L	L	L	H	H	L	L	H	L	L	2	2
3	L	L	H	H	H	L	H	H	L	L	H	H	H	.3	3.
4	L	H	L	L	L	L	H	H	L	H	L	L	L	4	4
5	L	H	L	H	H	L	H	H	L	H	L	H	H	.5	5.
6	L	H	H	L	L	L	H	H	L	H	H	L	L	6	6
7	L	H	H	H	H	L	H	H	L	H	H	H	H	.7	7.
8	H	L	L	L	L	L	H	H	H	L	L	L	L	8	8
9	H	L	L	H	H	L	H	H	H	L	L	H	H	.9	9.
A	H	L	H	L	L	L	H	H	H	L	H	L	L	A	A
MINUS SIGN	H	L	H	H	H	L	H	H	H	L	H	H	H	.−	−.
C	H	H	L	L	L	L	H	H	H	H	L	L	L	C	C
BLANK	H	H	L	H	H	L	H	H	H	H	L	H	H	.	.
E	H	H	H	L	L	L	H	H	H	H	H	L	L	E	E
F	H	H	H	H	H	L	H	H	H	H	H	H	H	.F	F.
BLANK	X	X	X	X	X	X	L	H	X	X	X	X	X		
LED TEST	X	X	X	X	X	X	X	L	X	X	X	X	X	.8	8.

H = high level, L = low level, X = irrelevant.
DP input has arbitrarily been shown activated (high) on every other line of the table.

description (continued)

The TTL MSI circuits contain the equivalent of 78 gates on a single chip. Logic inputs and outputs are completely TTL/DTL compatible. The buffered inputs are implemented with relatively large resistors in series with the bases of the input transistors to lower drive-current requirements to one-half of that required for a standard Series 54/74 TTL input.

Some of the additional features of these displays are as follows:

- Latched BCD and decimal point logic outputs provided to drive logic processors simultaneously with the displayed data
- Minimum number of inputs required . . . 4-line BCD plus decimal point
- Overriding blanking for suppressing entire display or for pulse-modulation of LED brightness
- LED test input to simultaneously turn on all display segments and decimal point
- Can be operated in a real-time mode or latched-update-only mode by use of the latch strobe input
- Displays numbers 0 thru 9 as well as A, C, E, F, or minus sign
- Can be blanked by entry of BCD 13 or by use of the blanking input
- Decimal point controlled independently with decimal-point latch
- Constant-current-source TTL-LED interface for optimum performance.

The latch outputs except Q_{DP} are active pull-up, and each one, including Q_{DP}, is capable of driving three standard Series 54/74 loads. The LED driver outputs are designed specifically to maintain a relatively constant on-level current of approximately 15 milliamperes through LED segments "a" through "g" and seven milliamperes through the decimal point LED. All inputs are diode-clamped to minimize transmission-line effects, thereby simplifying system design. Power dissipation is typically 800 milliwatts with all segments on.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply Voltage, V_{CC} (See Note 1): Continuous	5.5 V
Nonrepetitive Peak, $t_w \leq 100$ ms	7 V
Input Voltage (See Note 1)	5.5 V
Operating Free-Air Temperature Range	0°C to 70°C
Storage Temperature Range	−55°C to 100°C

NOTE 1: Voltage values are with respect to network ground terminal.

recommended operating conditions

			MIN	NOM	MAX	UNIT
Supply Voltage, V_{CC}			4.75	5	5.25	V
Normalized Fan-out from each output, N (to Series 54 Integrated Circuits)	Low Logic Level	Any Output			3	
	High Logic Level	Q_{DP}			3	
		Q_A, Q_B, Q_C, Q_D			6	
Latch Strobe Pulse Width, t_w			45			ns
Setup Time, t_{setup} (See Note 2)			60			ns
Hold Time, t_{hold} (See Note 3)			0			ns

NOTES: 2. Setup time is the interval immediately preceeding the positive-going transition of the latch strobe during which interval the data to be latched must be maintained at the latch inputs to ensure its recognition.

3. Hold time is the interval immediately following the positive-going transition of the latch strobe during which interval the data to be latched must be maintained at the latch inputs to ensure its continued recognition.

operating characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP†	MAX	UNIT
I_v	Luminous Intensity (See Note 4)	Figure 8	V_{CC} = 5 V	700	1200		µcd
		Decimal Point		40	70		
λ_P	Wavelength at Peak Emission		V_{CC} = 5 V, See Note 5	640	660	680	nm
B	Spectral Bandwidth between Half-Power Points		V_{CC} = 5 V, See Note 5		20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_I	Input Clamp Voltage		V_{CC} = 4.75 V, I_I = −12 mA			−1.5	V
V_{OH}	High-Level Output Voltage	Q_{DP}	V_{CC} = 4.75 V, I_{OH} = −120 µA	2.4			V
		Q_A, Q_B, Q_C, Q_D	V_{CC} = 4.75 V, I_{OH} = −240 µA				
V_{OL}	Low-Level Output Voltage		V_{CC} = 4.75 V, I_{OL} = 4.8 mA			0.4	V
I_I	Input Current at Maximum Input Voltage		V_{CC} = 5.25 V, V_I = 5.5 V			1	mA
I_{IH}	High-Level Input Current		V_{CC} = 5.25 V, V_I = 2.4 V			20	µA
I_{IL}	Low-Level Input Current		V_{CC} = 5.25 V, V_I = 0.4 V			−0.8	mA
I_{OS}	Short-Circuit Output Current	Q_A, Q_B, Q_C, Q_D	V_{CC} = 5.25 V	−9		−27.5	mA
		Q_{DP}		−1		−3.2	
I_{CC}	Supply Current		V_{CC} = 5.25 V, All Inputs at 0 V		160	240	mA

†All typical values are at V_{CC} = 5 V.

NOTES: 4. Luminous intensity is measured with a solar cell and filter combination which approximates the CIE (International Commission on Illumination) eye-response curve.

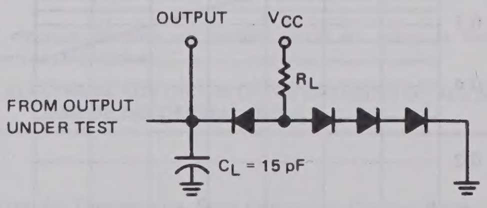
5. These parameters are measured with all LED segments and the decimal point on.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	A, B, C, D, DP	Q_A, Q_B, Q_C, Q_D, Q_{DP}	C_L = 15 pF, R_L = 1.2 kΩ, See Figure 1		35		ns
t_{PHL}					40		ns

t_{PLH} ≡ Propagation delay time, low-to-high-level output
t_{PHL} ≡ Propagation delay time, high-to-low-level output

PARAMETER MEASUREMENT INFORMATION



NOTES: A. C_L includes probe and jig capacitance.
B. All diodes are 1N3064.
C. Measurements made with latch strobe input grounded.

LOAD CIRCUIT—FIGURE 1

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

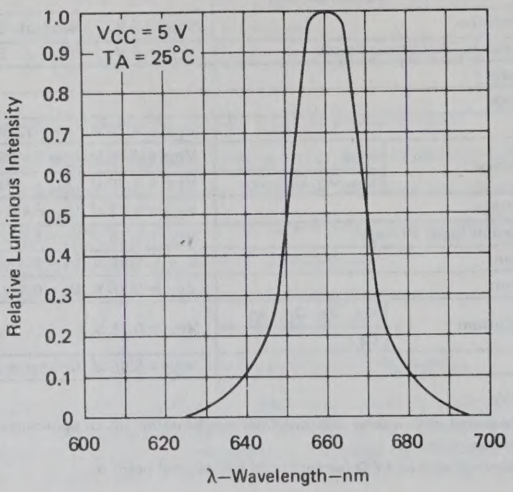


FIGURE 2

RELATIVE LUMINOUS INTENSITY vs FREE-AIR TEMPERATURE

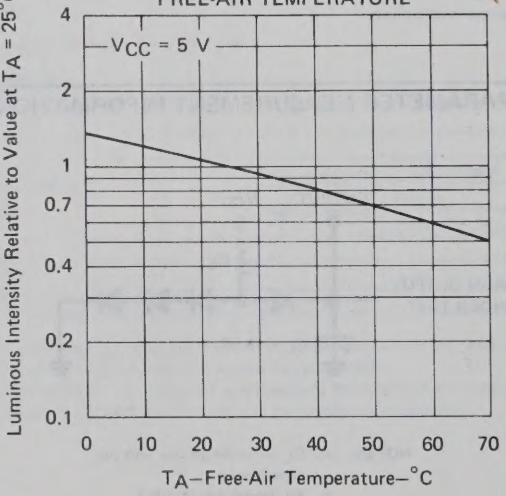


FIGURE 3

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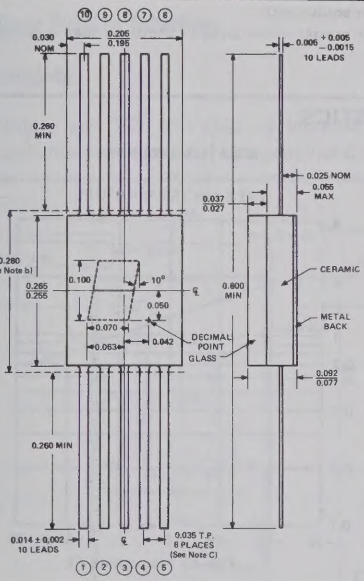
TYPE TIL310
BULLETIN NO. DL-S 7111552, SEPTEMBER 1971

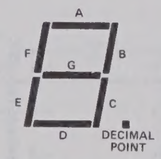
SOLID-STATE NUMERIC DISPLAY WITH RIGHT-HAND DECIMAL

- Hermetic Package
- 0.100-Inch-High Character
- High Brightness
- Low Power Requirements
- Single-Plane Visibility
- Compatible with Most TTL and DTL Circuits

mechanical data

The display and decimal are mounted in a metal and ceramic package similar to the TI integrated circuit flat packages. A glass window is the final closure.


⑩ ⑨ ⑧ ⑦ ⑥
0.030 NOM
0.205
0.195
0.006 + 0.005 − 0.0015
10 LEADS
0.260 MIN
0.025 NOM
0.055 MAX
0.037
0.027
0.280 (See Note b)
0.265
0.255
0.100
10°
℄
0.050
0.800 MIN
CERAMIC
METAL BACK
0.070
0.063
0.042
DECIMAL POINT
GLASS
0.092
0.077
0.260 MIN
0.014 ± 0.002
10 LEADS
℄
0.035 T.P.
8 PLACES
(See Note C)
① ② ③ ④ ⑤


A
F
B
G
E
C
D
DECIMAL POINT

SEGMENT
DENTIFICATION

PIN 1 ANODE E
PIN 2 ANODE D
PIN 3 ALL CATHODES
PIN 4 ANODE C
PIN 5 ANODE DP
PIN 6 ANODE B
PIN 7 ANODE A
PIN 8 ALL CATHODES
PIN 9 ANODE G
PIN 10 ANODE F

NOTES:
a. All dimensions are in inches.
b. This dimension determines a zone within which all body and lead irregularities lie.
c. Lead centerlines are located within 0.005 of true position (T.P.) relative to body centerlines.
d. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.

THE PACKAGE BACK IS IN ELECTRICAL CONTACT WITH THE CATHODES OF ALL SEGMENTS AND OF THE DECIMAL POINT

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Decimal Point	4 V
Peak Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1 and 2), Each Segment or Decimal Point	150 mA
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 3), Each Segment or Decimal Point	10 mA
Operating Free-Air Temperature Range	−55°C to 70°C
Storage Temperature Range	−55°C to 125°C

NOTES:
1. Derate linearly to 75 mA at 70°C free-air temperature at the rate of 1.67 mA/°C.
2. This value applies for PRR ⩾ 100 Hz, duty cycle ⩽ 1/15.
3. Derate linearly to 5 mA at 70°C free-air temperature at the rate of 0.11 mA/°C.

TYPE TIL310
7-SEGMENT NUMERIC DISPLAY

operating characteristics of each segment or decimal at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
L_V	Luminance (Photometric Brightness, See Notes 4, 5, and 6)	$I_F = 5$ mA	200	600		fL
λ_P	Wavelength at Peak Emission		6300	6500	6700	Å
B	Spectral Bandwidth between Half-Power Points			200		Å
V_F	Static Forward Voltage			1.65	1.9	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	$I_F = 10$ mA, $T_A = -55$°C to 70°C		−1.4		mV/°C
I_R	Static Reverse Current	$V_R = 4$ V			100	µA

NOTES: 4. Luminance may also be measured in candelas per square foot (cd/ft^2) or candelas per square meter (cd/m^2). To convert foot-lamberts to these units use the following equivalencies: 1 fL = (1/π)cd/ft^2 = 3.4263 cd/m^2.

5. Luminance is measured with a Photo Research Brightness Spot Meter (or equivalent).

6. For any given average forward current, brightness will be the same or greater under pulsed conditions than it would be under steady-state conditions.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

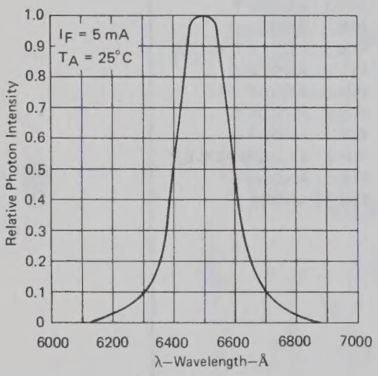


FIGURE 1

RELATIVE LUMINANCE
vs
FREE-AIR TEMPERATURE

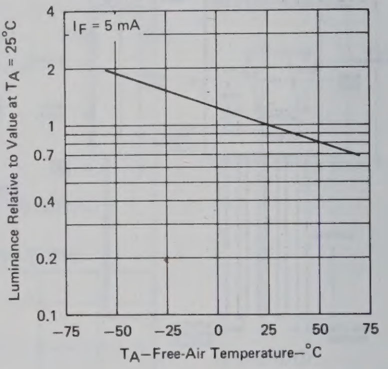


FIGURE 2

FORWARD CONDUCTION CHARACTERISTICS

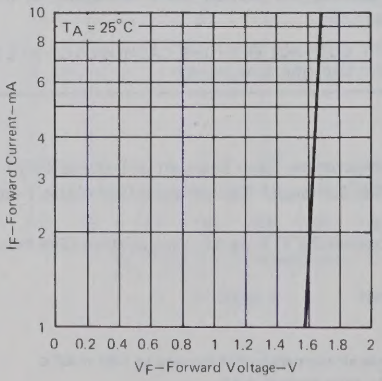


FIGURE 3

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TYPE TIL311
HEXADECIMAL DISPLAY WITH LOGIC

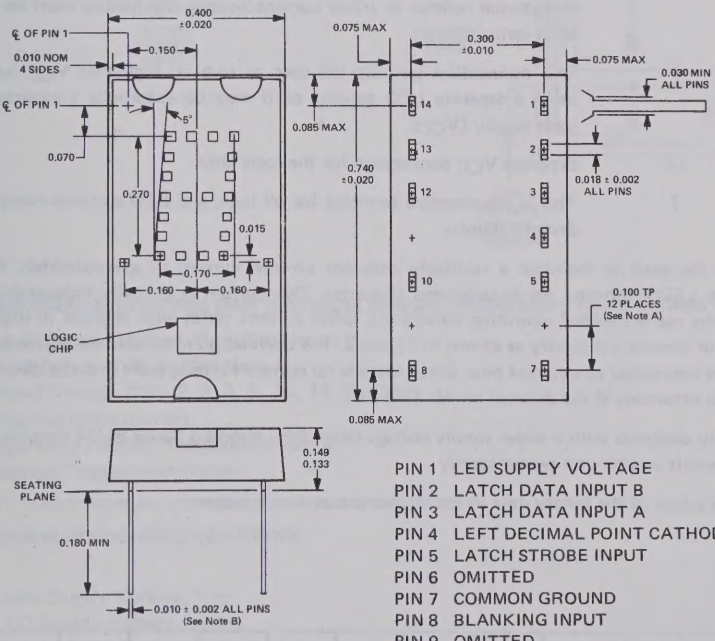
TYPE TIL311
BULLETIN NO. DL-S 7211653, MARCH 1972

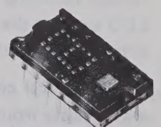
SOLID-STATE VISIBLE HEXADECIMAL DISPLAY WITH INTEGRAL TTL CIRCUIT TO ACCEPT, STORE, AND DISPLAY 4-BIT BINARY DATA

- 0.270-Inch-High Character
- High Brightness
- Left-and-Right-Hand Decimals
- Separate LED and Logic Power Supplies May Be Used
- Easy System Interface
- Single-Plane Wide-Angle Visibility
- Internal TTL MSI Chip with Latch, Decoder, and Driver
- Operates from 5-Volt or 6-Volt Supply
- Constant-Current Drive for Hexadecimal Characters

mechanical data

The display and TTL MSI chip are mounted on a lead-frame assembly which is then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.


0.400
±0.020
℄ OF PIN 1
0.010 NOM
4 SIDES
0.150
℄ OF PIN 1
5°
0.070
0.270
0.015
0.170
0.160
0.160
LOGIC CHIP
0.075 MAX
0.085 MAX
0.740
±0.020
0.085 MAX
0.300
±0.010
0.075 MAX
0.030 MIN
ALL PINS
0.018 ± 0.002
ALL PINS
0.100 TP
12 PLACES
(See Note A)
14
13
12
10
8
1
2
3
4
5
7
0.149
0.133
SEATING PLANE
0.180 MIN
0.010 ± 0.002 ALL PINS
(See Note B)



PIN 1 LED SUPPLY VOLTAGE
PIN 2 LATCH DATA INPUT B
PIN 3 LATCH DATA INPUT A
PIN 4 LEFT DECIMAL POINT CATHODE
PIN 5 LATCH STROBE INPUT
PIN 6 OMITTED
PIN 7 COMMON GROUND
PIN 8 BLANKING INPUT
PIN 9 OMITTED
PIN 10 RIGHT DECIMAL POINT CATHODE
PIN 11 OMITTED
PIN 12 LATCH DATA INPUT D
PIN 13 LATCH DATA INPUT C
PIN 14 LOGIC SUPPLY VOLTAGE, V_{CC}

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within ±0.010 of its true longitudinal position relative to pins 1 and 14.
B. Lead dimensions are not controlled above the seating plane.
C. Dimensions associated with position of LED's are between centerlines and are nominal.
D. All dimensions are in inches unless otherwise specified.

TYPE TIL311
HEXADECIMAL DISPLAY WITH LOGIC

description

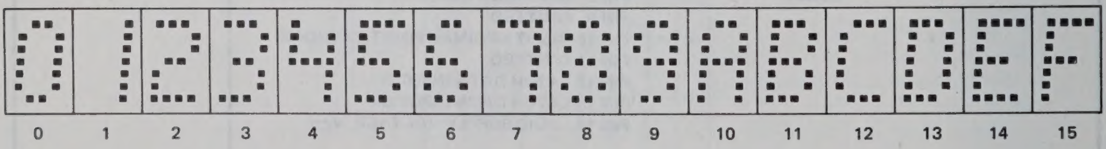
This hexadecimal display contains a four-bit latch, decoder, driver, and 4 X 7 light-emitting-diode (LED) character with two externally-driven decimal points in a 14-pin package. A description of the functions of the inputs of this device follows.

FUNCTION	PIN NO.	DESCRIPTION
LATCH STROBE INPUT	5	When low, the data in the latches follow the data on the latch data inputs. When high, the data in the latches will not change. If the display is blanked and then restored while the enable input is high, the previous character will again be displayed.
BLANKING INPUT	8	When high, the display is blanked regardless of the levels of the other inputs. When low, a character is displayed as determined by the data in the latches. The blanking input may be pulsed for intensity modulation.
LATCH DATA INPUTS (A, B, C, D)	3, 2, 13, 12	Data on these inputs are entered into the latches when the enable input is low. The binary weights of these inputs are A = 1, B = 2, C = 4, D = 8.
DECIMAL POINT CATHODES	4, 10	These LEDs are not connected to the logic chip. If a decimal point is used, an external resistor or other current-limiting mechanism must be connected in series with it.
LED SUPPLY	1	This connection permits the user to save on regulated V_{CC} current by using a separate LED supply, or it may be externally connected to the logic supply (V_{CC}).
LOGIC SUPPLY (V_{CC})	14	Separate V_{CC} connection for the logic chip.
COMMON GROUND	7	This is the negative terminal for all logic and LED currents except for the decimal points.

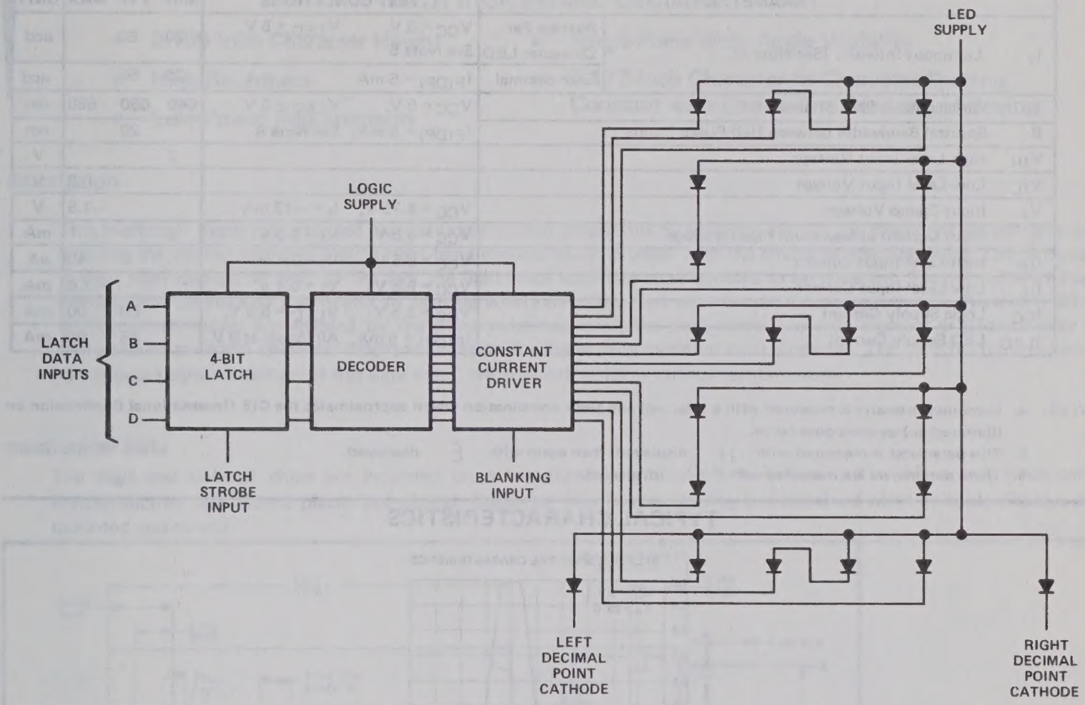
The LED driver outputs are designed to maintain a relatively constant on-level current of approximately five milliamperes through each of the LED's forming the hexadecimal character. This current is virtually independent of the LED supply voltage within the recommended operating conditions. Drive current varies with changes in logic supply voltage resulting in a change in luminous intensity as shown in Figure 2. The decimal point anodes are connected to the LED supply; the cathodes are connected to external pins. Since there is no current limiting built into the decimal point circuits, this must be provided externally if the decimal points are used.

The TTL MSI chip is specially designed with a wider supply voltage range than standard Series 54/74 circuits so that it will operate from either a five-volt or a six-volt power supply.

The resultant displays for the values of the binary data in the latches are as shown below.



functional block diagram


LED SUPPLY
LOGIC SUPPLY
A
B
C
D
LATCH DATA INPUTS
4-BIT LATCH
DECODER
CONSTANT CURRENT DRIVER
LATCH STROBE INPUT
BLANKING INPUT
LEFT DECIMAL POINT CATHODE
RIGHT DECIMAL POINT CATHODE

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Logic Supply Voltage, V_{CC} (See Note 1)	7 V
LED Supply Voltage (See Note 1)	7 V
Input Voltage (Pins 2, 3, 5, 8, 12, 13; See Note 1)	5.5 V
Decimal Point Current	20 mA
Operating Free-Air Temperature Range	0°C to 70°C
Storage Temperature Range	–55°C to 100°C

NOTE 1: Voltage values are with respect to common ground terminal.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Logic Supply Voltage, V_{CC}	4.5	5	6.5	V
LED Supply Voltage, V_{LED}	4	5	7	V
Decimal Point Current, $I_{F(DP)}$		5		mA
Latch Strobe Pulse Width, t_w	40			ns
Setup Time, t_{setup} (See Note 2)	50			ns
Hold Time, t_{hold} (See Note 3)	40			ns

NOTES: 2. Setup time is the interval immediately preceding the positive-going transition of the latch strobe input during which interval the data to be displayed must be maintained at the latch data inputs to ensure its recognition.

3. Hold time is the interval immediately following the positive-going transition of the latch strobe input during which interval the data to be displayed must be maintained at the latch data inputs to ensure its continued recognition.

TYPE TIL311
HEXADECIMAL DISPLAY WITH LOGIC

operating characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_v	Luminous Intensity (See Note 4)	Average Per Character LED	$V_{CC} = 5$ V, $V_{LED} = 5$ V, See Note 5	20	50		µcd
		Each decimal	$I_{F(DP)} = 5$ mA	20	50		µcd
λ_P	Wavelength at Peak Emission		$V_{CC} = 5$ V, $V_{LED} = 5$ V, $I_{F(DP)} = 5$ mA, See Note 6	640	660	680	nm
B	Spectral Bandwidth between Half-Power Points				20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_I	Input Clamp Voltage		$V_{CC} = 4.75$ V, $I_I = -12$ mA			−1.5	V
I_I	Input Current at Maximum Input Voltage		$V_{CC} = 5.5$ V, $V_I = 5.5$ V			1	mA
I_{IH}	High-Level Input Current		$V_{CC} = 5.5$ V, $V_I = 2.4$ V			40	µA
I_{IL}	Low-Level Input Current		$V_{CC} = 5.5$ V, $V_I = 0.4$ V			−1.6	mA
I_{CC}	Logic Supply Current		$V_{CC} = 5.5$ V, $V_{LED} = 5.5$ V, $I_{F(DP)} = 5$ mA, All inputs at 0 V		60	90	mA
I_{LED}	LED Supply Current				45	90	mA

NOTES: 4. Luminous intensity is measured with a solar cell and filter combination which approximates the CIE (International Commission on Illumination) eye-response curve.

5. This parameter is measured with A displayed, then again with E displayed.

6. These parameters are measured with .B. displayed.

TYPICAL CHARACTERISTICS

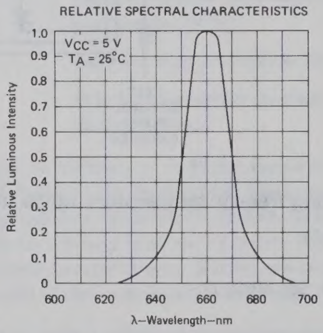


FIGURE 1

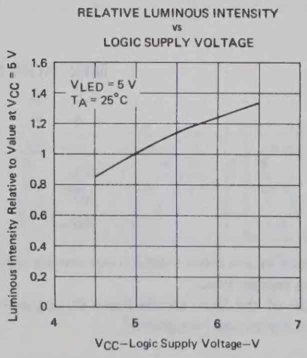


FIGURE 2

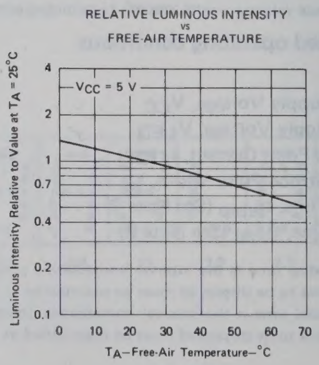


FIGURE 3

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TYPE TIL360
BULLETIN NO. DL-S 7211498, MARCH 1972

SOLID-STATE MULTIPLE SEVEN-SEGMENT VISIBLE DISPLAY WITH RIGHT-HAND DECIMAL

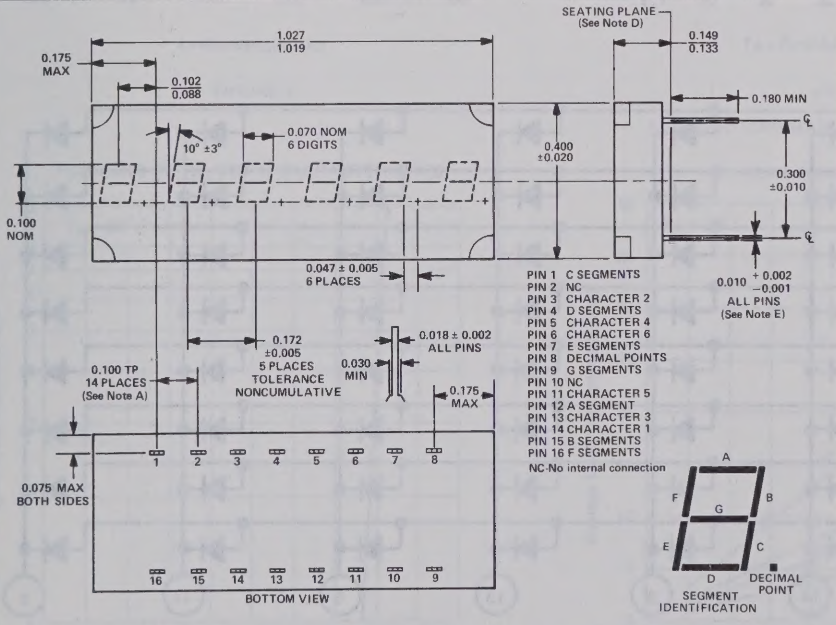
- 0.100-Inch Character Height
- High Brightness
- Low Power Requirements
- Single-Plane Wide-Angle Visibility
- 0.172-Inch Character-to-Character Spacing, Constant with End-to-End Stacking of Devices

description

This multidigit display is intended for use under pulsed conditions by enabling each of the characters sequentially and enabling the desired segments and/or right-hand decimal point in phase with the character enabling pulse. The pulse rate is kept high enough so that to the eye the light from each character appears to be constant. Two or more of these devices may be stacked end-to-end to provide additional characters with constant spacing between characters. When additional characters are enabled by the same pulse sequence, the peak current in each segment or decimal may be increased to maintain character brightness despite the lower duty cycle for each character. The modifications shown in the product options section of this data sheet, are available to form various combinations.

mechanical data

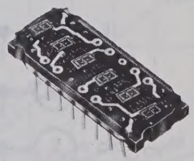
The digit and decimal chips are mounted on a lead-frame assembly which is then cast within a red, electrically nonconductive, transparent plastic compound. Character-to-character spacing is maintained when multiple displays are mounted end-to-end.


SEATING PLANE (See Note D)
1.027
1.019
0.175 MAX
0.102
0.088
0.149
0.133
0.180 MIN
0.070 NOM 6 DIGITS
10° ±3°
0.400 ±0.020
0.300 ±0.010
0.100 NOM
0.047 ± 0.005 6 PLACES
0.010 +0.002 −0.001 ALL PINS (See Note E)
0.172 ±0.005 5 PLACES TOLERANCE NONCUMULATIVE
0.018 ± 0.002 ALL PINS
0.030 MIN
0.100 TP 14 PLACES (See Note A)
0.175 MAX
0.075 MAX BOTH SIDES
1
2
3
4
5
6
7
8
16
15
14
13
12
11
10
9
BOTTOM VIEW
A
F
G
B
E
C
D
DECIMAL POINT
SEGMENT IDENTIFICATION

PIN 1	C SEGMENTS
PIN 2	NC
PIN 3	CHARACTER 2
PIN 4	D SEGMENTS
PIN 5	CHARACTER 4
PIN 6	CHARACTER 6
PIN 7	E SEGMENTS
PIN 8	DECIMAL POINTS
PIN 9	G SEGMENTS
PIN 10	NC
PIN 11	CHARACTER 5
PIN 12	A SEGMENT
PIN 13	CHARACTER 3
PIN 14	CHARACTER 1
PIN 15	B SEGMENTS
PIN 16	F SEGMENTS

NC-No internal connection

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 1 and 16.
B. Centerlines of character segments and decimal points are shown.
C. The angle between the vertical axis of any digit and the vertical axis of the package is 10° ± 3°. The angle between the vertical axes of adjacent digits is a maximum of 4°.
D. The maximum variation in vertical position is 0.010 inch between any two digits in the package and 0.005 inch between any two adjacent digits.
E. Lead dimensions are not controlled above the seating plane.
F. All dimensions are in inches unless otherwise specified.



TYPE TIL360
MULTIDIGIT NUMERIC DISPLAY

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Decimal Point	2 V
Peak Forward Current, Each Segment or Decimal Point (See Note 1)	150 mA
Average Forward Current, Each Segment or Decimal Point (See Note 2)	10 mA
Operating Free-Air Temperature Range	0°C to 70°C
Storage Temperature Range	−55°C to 100°C

operating characteristics of each segment or decimal at 25°C free-air temperature

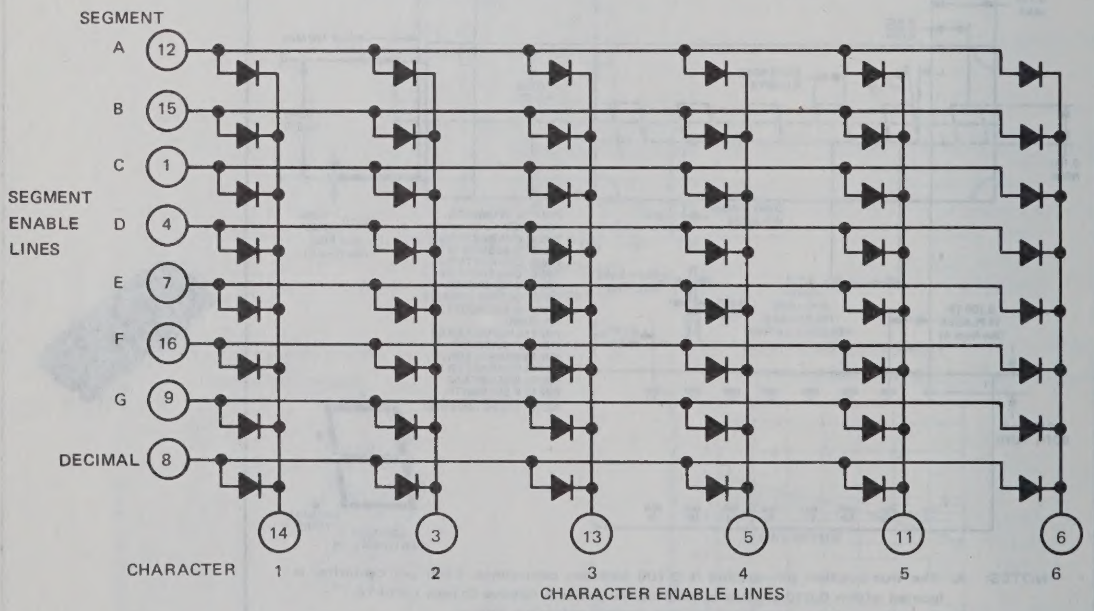
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V Luminous Intensity (See Note 3)	Segment	I_{FM} = 10 mA, t_w = 40 μs, duty cycle = 1/6	8	16		μcd
	Decimal Point		7	14		
λ_p Wavelength at Peak Emission			640	660	680	nm
B Spectral Bandwidth between Half-Power Points				20		nm
V_F Static Forward Voltage		I_F = 10 mA		1.65	2	V

NOTES: 1. This value applies for PRR ⩾ 100 Hz, duty cycle ⩽ 1/15.

2. This value applies for a maximum averaging time of 10 ms.

3. Luminous intensity is measured with a solar cell and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

schematic



TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

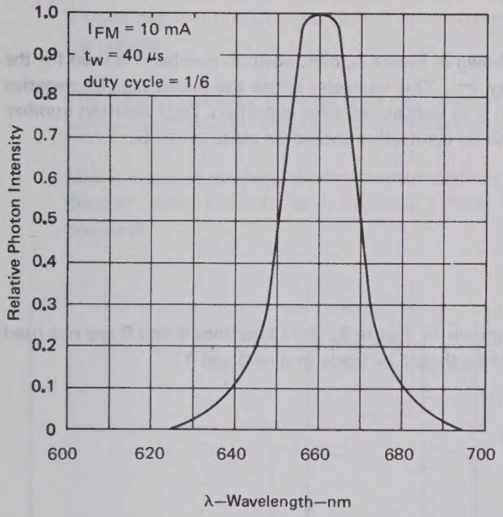


FIGURE 1

RELATIVE RADIANT INTENSITY
vs
FREE-AIR TEMPERATURE

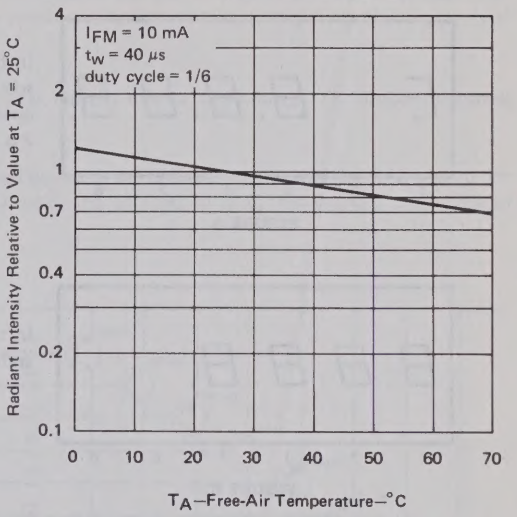


FIGURE 2

FORWARD CONDUCTION CHARACTERISTICS

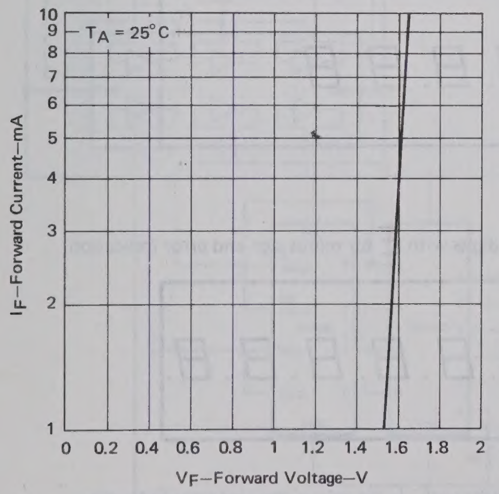


FIGURE 3

AVERAGE LUMINOUS INTENSITY (PER SEGMENT)
vs
PEAK FORWARD CURRENT

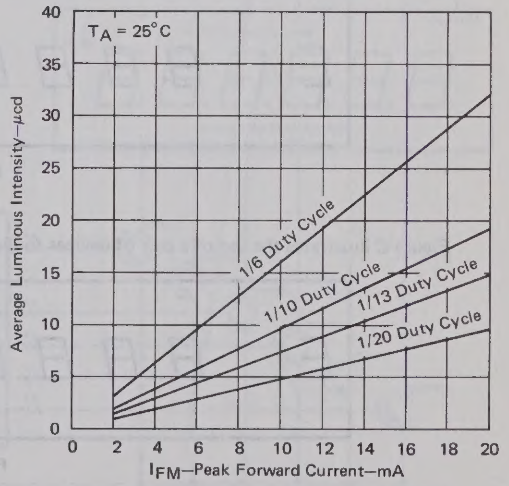


FIGURE 4

PRODUCT OPTIONS

Texas Instruments can supply multidigit displays that are variations of the TIL360. These special devices can be arranged in various configurations, two of which are illustrated in Figures A and B. To describe the displays, digit positions are numbered 1 through 6, left to right.

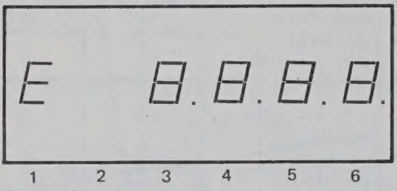


FIGURE A

In the device shown in Figure A, digit position number 1 is used for the special character E. This character forms the minus sign for negative quantities or an E to indicate an error condition. Digit position number 2 is not used and no connection should be made to pin 3.

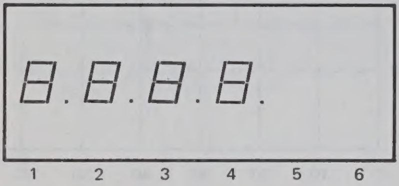


FIGURE B

In the device shown in Figure B, digit positions 5 and 6 are not used and no connections should be made to pins 6 and 11.

The TIL360 package is designed so that two or more displays can be mounted end-to-end maintaining the character-to-character dimension between digits. Two of many possible combinations are shown in Figure C and Figure D.

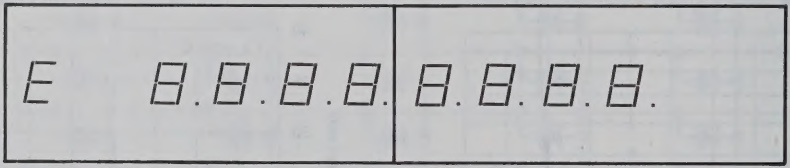


FIGURE C

Figure C illustrates the use of a pair of devices to display eight digits with E for minus sign and error indication.

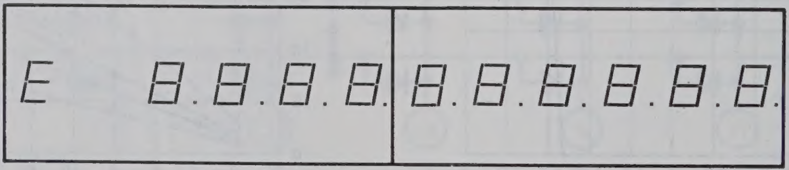


FIGURE D

Figure D illustrates the use of a pair of devices to display ten digits with E for minus sign and error indication.

In addition to the devices shown, other configurations are available on a contract basis.

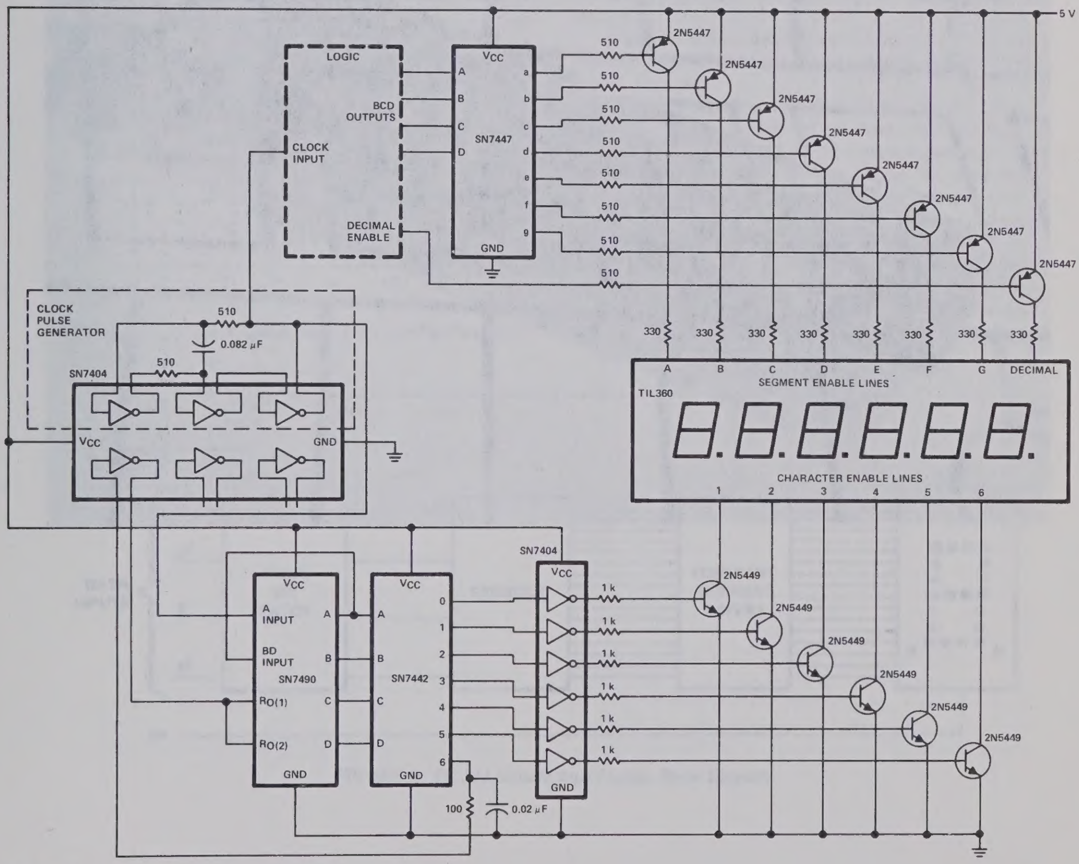
TYPICAL APPLICATION DATA

Figure E shows decoder driver circuitry that can interface the TIL360 six-digit display with TTL logic. It also shows a multiplex circuit used to turn each digit on in sequence at a one-sixth duty cycle.

The BCD code, generated by the user's specific logic circuitry and applied as input to the SN7447, will be decoded into a seven-segment output. This output drives p-n-p transistors which supply current to operate p-n junction segments of the display.

The 330-ohm resistor in series with each segment limits the peak current to nine milliamperes. The display brightness may be controlled by selection of the resistor value.

Multiplexing or strobing the digits sequentially is accomplished by use of the SN7490 counter and SN7442 4-to-10-line decoder. After counting to 6 the output from the SN7442 resets the SN7490 to zero, thus giving a duty cycle of one-sixth.


5 V
LOGIC
BCD OUTPUTS
CLOCK INPUT
DECIMAL ENABLE
Vcc
A
B
C
D
a
b
c
d
e
f
g
SN7447
GND
510
2N5447
330
A
B
C
D
E
F
G
DECIMAL
SEGMENT ENABLE LINES
TIL360
CHARACTER ENABLE LINES
1
2
3
4
5
6
CLOCK PULSE GENERATOR
510
0.082 μF
510
SN7404
Vcc
GND
SN7490
A INPUT
BD INPUT
RO(1)
RO(2)
SN7442
0
1
2
3
4
5
6
100
0.02 μF
1 k
2N5449

Resistor values are in ohms.

FIGURE E

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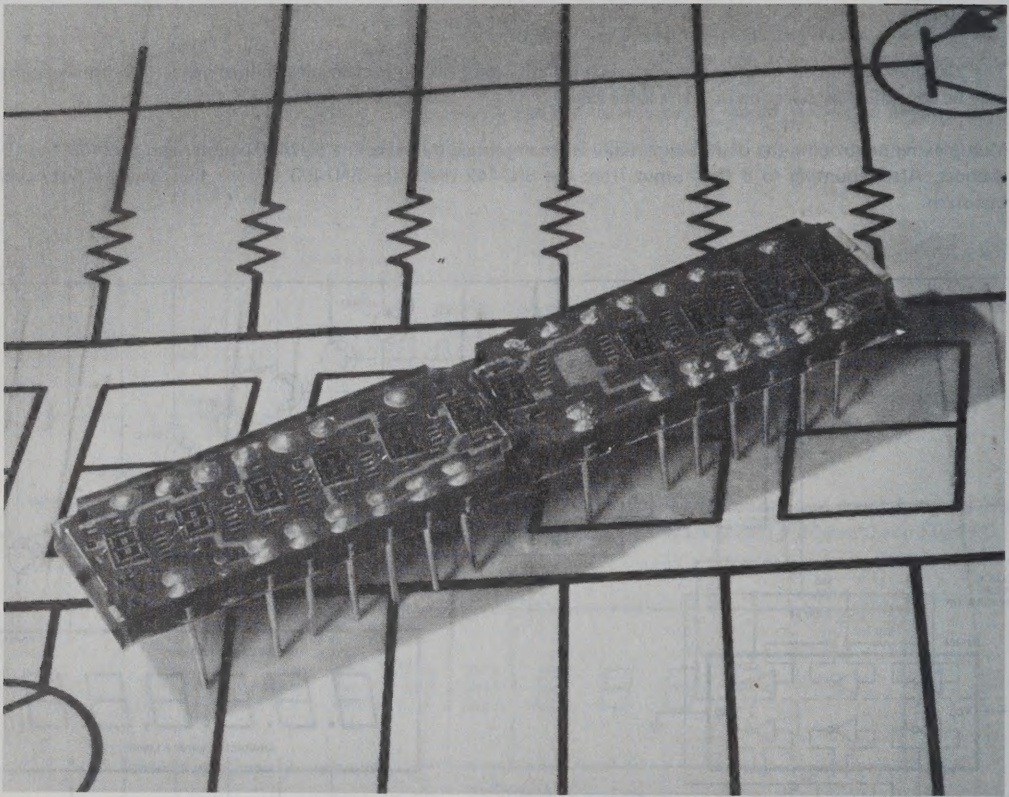


TIXL311 HEXADECIMAL LED DISPLAY

by Bruce E. Aldridge

The TIL311 is designed to store and display decimal and hexadecimal data. The device consists of an MSI logic chip to perform logic and storage functions plus a light emitting diode (LED) display in a single 14-pin dual in-line package.

It accepts parallel 8-4-2-1 data on four input lines and displays the corresponding decimal or hexadecimal character on a 4 by 7 dot matrix. Figure 1 illustrates the hexadecimal character representation for the decimal numbers 0 through 15. The logic levels are designed to be TTL compatible: a logical one is high, 2 V to 5 V; a logical zero is low, 0 V to 0.8 V.

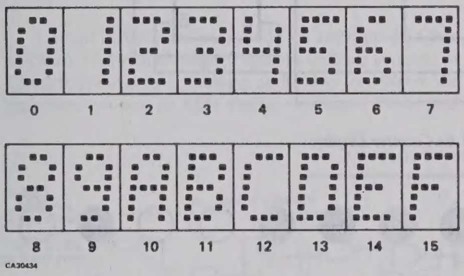


FIGURE 1. TIL311 Hexadecimal Character Configuration

The block diagram in Figure 2 shows the major sections of the TIL311; Latches, Decoder, Current Drive, and LED Display. The inputs are DATA, LATCH STROBE, BLANKING, and DP. DATA is parallel 8-4-2-1 coded data. When LATCH STROBE is low the data in the latches follow the data inputs. When LATCH STROBE goes high the data on the input lines at strobe time is stored in the latches.

The 4-bit code is decoded and the required diodes are turned on via the Constant Current Drivers to display the proper character.

The LED display contains two decimal points: one to the left and one to the right of the character. A low input to one of the DP inputs will turn that decimal point on.

BLANKING must be low to display the character. When BLANKING goes high, the character is turned off regardless of the inputs. The BLANKING input does not change the data stored in the latches. BLANKING may be pulsed to intensity modulate the display. The apparent brightness of the display is proportional to the duty cycle of the modulating signal, assuming a frequency high enough to avoid visible flicker. For example, at 1 kHz, a 50% duty

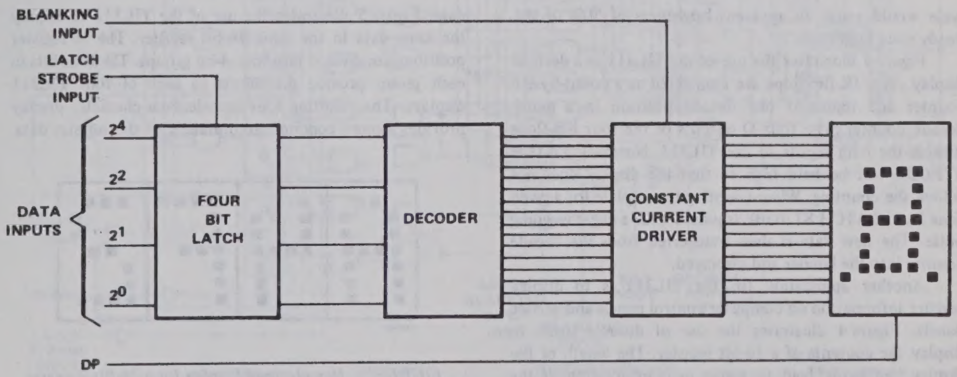


FIGURE 2. TIL311 Hexadecimal Display Block Diagram

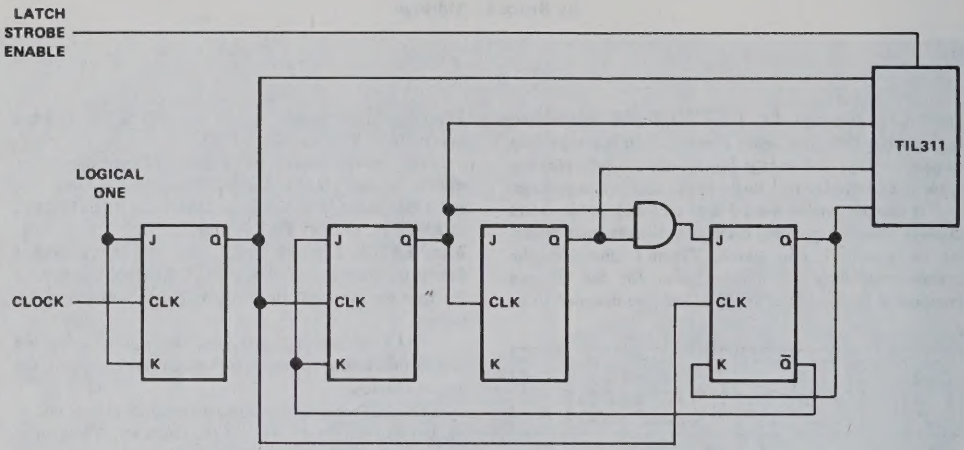


FIGURE 3. TIL311 Used As Counter Display

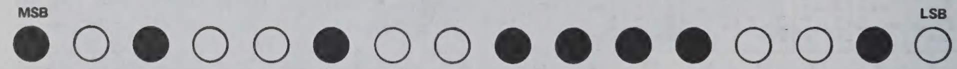


FIGURE 4. Discrete Light Display for a 16-Bit Register

cycle would cause an apparent brightness of 50% of the steady state brightness.

Figure 3 illustrates the use of the TIL311 as a decimal display. The JK flip-flops are connected as a count-by-ten counter and represent one decade position in a multidecade counter. The four Q outputs of the four flip-flops furnish the data inputs to the TIL311. Normally LATCH STROBE will be held high so that the display does not follow the counting. When counting is complete for a given time base, LATCH STROBE is pulsed with a negative-going pulse. The new data is then transferred from the decade counter into the latches and displayed.

Another application for the TIL311 is to display register information on computer control panels and service panels. Figure 4 illustrates the use of discrete lights to display the contents of a 16-bit register. The length of the display can easily lead to errors in interpretation of the data. Figure 5 illustrates the use of the TIL311 to display the same data in the same 16-bit register. The 16 register positions are divided into four 4-bit groups. The four bits in each group provide the inputs to each of four TIL311 displays. The resulting four hexadecimal character display provides a more concise interpretation of the register data.

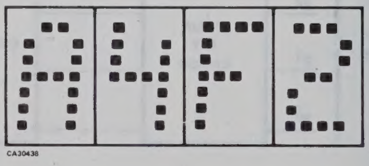


FIGURE 5. Hexadecimal Display for a 16-Bit Register

COUNTING CIRCUITS
USING TIL306 AND TIL308 LEDs

by
Bert Kehren
and
Bruce Aldridge

Digital instruments have experienced a constant evolution since 1960. Counters that once occupied several inches of rack space in a 19-inch rack have been replaced by units the size of a text book with performance characteristics surpassing the older models. A major contribution to these changes is the continued advances in solid state devices: integrated circuits have replaced the tubes and transistors and light emitting diodes (LEDs) have replaced the incandescent displays.

Texas Instruments has introduced a new product that simplifies further the design of systems utilizing counters or digital read-outs. By combining an IC chip to perform the logic function and an LED display in a single 16-pin dual in-line package, Texas Instruments has provided the designer a device that reduces the complexity of his system without reducing flexibility of design. Two of these devices are the TIL306 and TIL308. The TIL306 and TIL308 have decimal points to the left side of the character. The TIL307 and TIL309 have decimal points to the right side of the character, but are otherwise identical to the TIL306 and TIL308 respectively. They can be combined to count, store, and display data in multiple decade positions.

CIRCUIT DESCRIPTION

The TIL306, as shown in Figure 1, consists of four major sections: counter, latches, decoder/driver, and LED display.

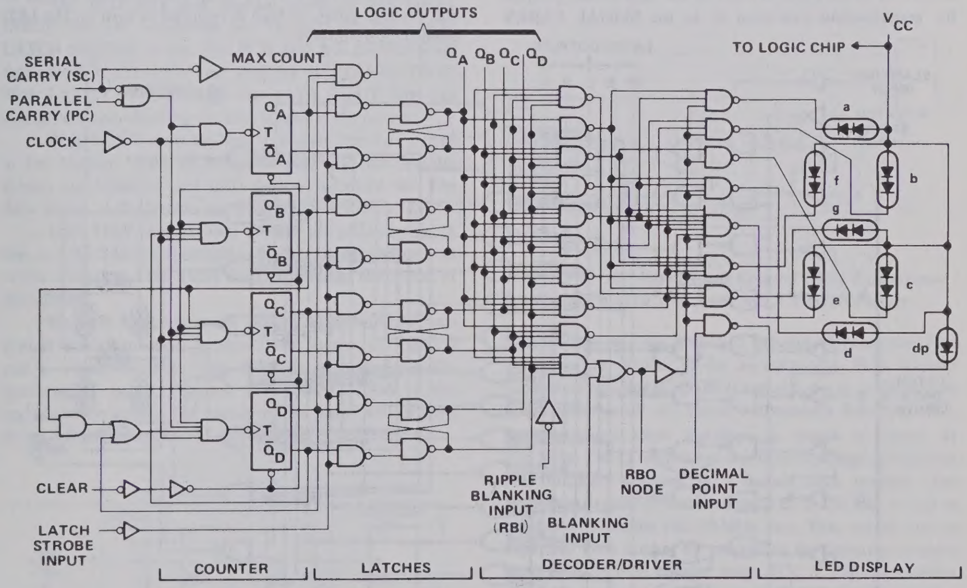

LOGIC OUTPUTS
SERIAL CARRY (SC)
PARALLEL CARRY (PC)
CLOCK
MAX COUNT
Q_A Q_B Q_C Q_D
V_{CC}
TO LOGIC CHIP
Q_A T $\bar{Q}_A$
Q_B T $\bar{Q}_B$
Q_C T $\bar{Q}_C$
Q_D T $\bar{Q}_D$
a
b
c
d
e
f
g
dp
CLEAR
LATCH STROBE INPUT
RIPPLE BLANKING INPUT (RBI)
BLANKING INPUT
RBO NODE
DECIMAL POINT INPUT
COUNTER
LATCHES
DECODER/DRIVER
LED DISPLAY

FIGURE 1. Functional Block Diagram of TIL306

The counter is connected as a synchronous counter. This configuration takes advantage of the minimal propogation delay to give maximum speed capability. Inputs to the counter are CLEAR, CLOCK, SERIAL CARRY, and PARALLEL CARRY. The counter and its inputs generate an output, MAX COUNT. Additional connections are LATCH STROBE, BLANKING, RIPPLE BLANKING, RBO, DECIMAL POINT and LOGIC OUTPUTS. All inputs and outputs are designed to be TTL compatible. A logical one (high) is a minimum of 2 V and a logical zero (low) is a maximum of 0.8 V. A low input to CLEAR will reset the counter to zero independently of any other input. As long as the input remains low the counter remains at zero. A high is required to allow the counter to count.

The CLOCK input is the signal to be counted. With an input the counter will advance from 0 to 9. At a count of 9 the counter automatically resets to 0 with the next pulse. The counter changes state on the positive-going edge of the clock pulse. The clock pulse to the counter is controlled by SERIAL CARRY and PARALLEL CARRY.

The MAX COUNT output goes low when the counter reaches a count of 9, and then goes high when the counter progresses to 0 on the next clock input. This output can be connected to the CLOCK input of the next decade position for asynchronous operation or to the SERIAL CARRY input of the next decade position for synchronous operation.

A high on SERIAL CARRY inhibits the counter and forces MAX COUNT to go high regardless of the state of the counter stages. When SERIAL CARRY and PARALLEL CARRY go low, the CLOCK is enabled to the counter stages and the MAX COUNT gate is allowed to sense the status of the counter. The logic level of SERIAL CARRY must not be allowed to change while CLOCK is low or erroneous counts may result.

PARALLEL CARRY permits look ahead carry inputs from lower order decade positions. A high input inhibits the clock to the counter stages. When PARALLEL CARRY and SERIAL CARRY go low the clock to the counter stages is enabled. The logic level of PARALLEL CARRY must not be allowed to change while CLOCK is low or erroneous counts may result.

LATCH STROBE transfers the data in the counter stages to the latch storage to be displayed. With LATCH STROBE low, the latch flip-flops follow the states of the counter flip-flops. When LATCH STROBE goes high, the counter data is stored in the latch flip-flops. The counter can continue to count while the previous information is stored in the latches.

The DECIMAL POINT input controls the display of the decimal point. A high is required to turn on the LED decimal point display.

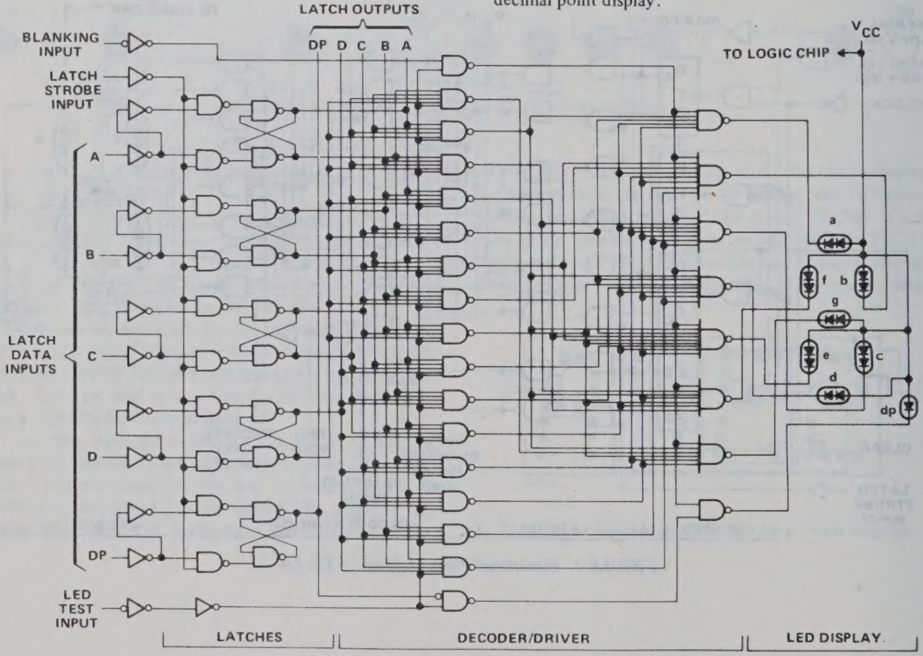


FIGURE 2. Functional Block Diagram of TIL308

A high on BLANKING inhibits the driver and gates and blanks the LED display. For normal operation, the BLANKING input must be low.

A low on RIPPLE BLANKING blanks the display if the latch flip-flops contain a count of zero. This combination also forces the RBO NODE to go low. By connecting the RBO NODE of one decade position to the RIPPLE BLANKING input of the next decade position, zero suppression can be achieved. This is discussed in detail in a later portion of this report, Counter Circuit Description. The RBO NODE has a resistor pullup which allows this output to be used as an input. A low level applied to RBO will blank the LED display independently of other input.

The TIL308 looks physically identical to the TIL306. However, the TIL306 contains a counter section: the TIL308 does not. The TIL308 accepts 8421 BCD code from external sources, stores it in latches, and displays the stored character by means of an LED display. As shown in Figure 2, the TIL308 consists of three major sections: latch, decoder/driver, and LED display.

The inputs and outputs, designed to be TTL compatible, consist of DATA INPUTS, DATA OUTPUTS, LATCH STROBE, BLANKING, and LED TEST.

The BCD data and decimal point on the DATA INPUT lines are transferred into the latch flip-flops when LATCH STROBE is low. The BCD data and decimal point data stored in the latches are available at DATA OUTPUT. With LATCH STROBE high the DATA INPUT lines can change without effecting the data stored in the latches.

BLANKING must be high to display the data stored in the latches. When BLANKING goes low, the decoder drivers are inhibited and LED display is turned off. The data stored in the latches are not effected by BLANKING.

LED TEST can be used to test the LED display. A low to LED TEST will override all other signals and turn all of the LEDs on. LED TEST does not change the status of the latches.

With the basic operation of the circuits outlined, two typical interconnection methods are shown in Figure 3 and 4. Figure 3 shows the TIL306 connected in the synchronous mode. Figure 4 shows the TIL306 in the asynchronous mode. The asynchronous mode will be used in the following example of a counter.

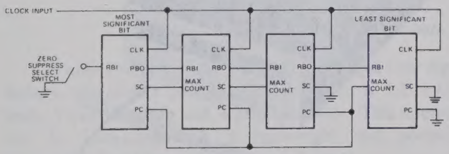


FIGURE 3. TIL306 Interconnect for Synchronous Count-Mode and High Order Zero Suppression.

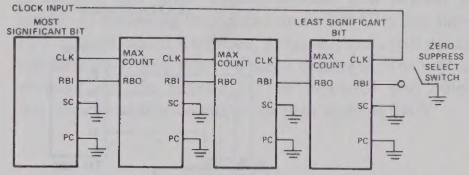


FIGURE 4. TIL306 Interconnect for Asynchronous Counting Mode and Low Order Zero Suppression.

COUNTER CIRCUIT DESCRIPTION

The counter is a major constituent in digital instruments. Digital Voltmeters, Frequency Counters, Event Counters, and Period Counters all have a circuit in common, very much like the one shown in Figure 4.

The circuit to be discussed in detail in this report incorporates both the TIL306 and the TIL308. One of the limiting factors of the TIL306 is that the counter typically does not count faster than 18 MHz. Combining the TIL306 with a TIL308 and feeding the TIL308 from a high speed counter expands the system to a much higher frequency. Figure 5 shows a BCD counter capable of working at 100 MHz. The circuit consists of two SN74S112 Schottky TTL circuits and one SN74S11 Schottky TTL circuit. This configuration results in an asynchronous BCD counter capable of dividing a 100 MHz signal down to 10 MHz. The speed is a result of Texas Instruments Schottky TTL devices which allow flip-flops to toggle in excess of 100 MHz. The Q outputs of the four flip-flops are fed into one TIL308, resulting in a decade with readout. The following decade position consists of a TIL306, which is capable of handling the 10 MHz rate. This circuit can be expanded even further by preceeding the Schottky counter stage with an ECL counter stage. ECL IC flip-flops with a 400 MHz toggle rate and discrete built ECL flip-flops with a toggle rate of 800 MHz are possible. Figure 6 shows a block diagram of a stage which is capable of counting up to 800 MHz. Since ECL levels do not coincide with TTL levels, an ECL-TTL converter is necessary. The output of the converter will drive the TIL308 without any interference caused by switching speed problems.

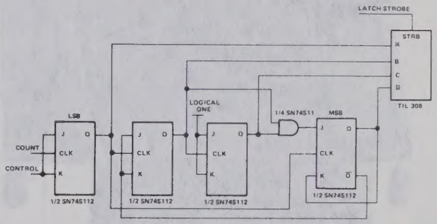


FIGURE 5. 100 MHz Decade Counter Using Texas Intruments Schottky TTL Logic and A TIL308 Display.

COUNTING CIRCUITS USING TIL306 AND TIL308 LEDs

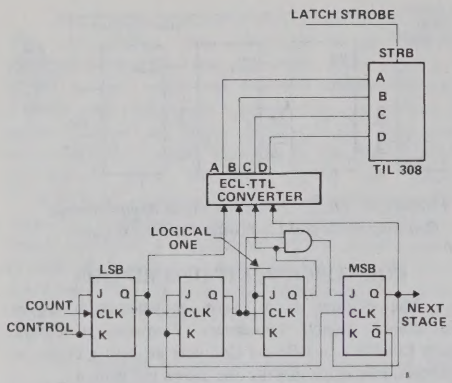

LATCH STROBE
STRB
A
B
C
D
TIL 308
A B C D
ECL-TTL CONVERTER
LOGICAL ONE
LSB
MSB
J Q
CLK
K
J Q
CLK
K
J Q
CLK
K
J Q
CLK
K Q̄
COUNT
CONTROL
NEXT STAGE

FIGURE 6. 800 MHz Decade Counter Using ECL Logic and A TIL308 Display.

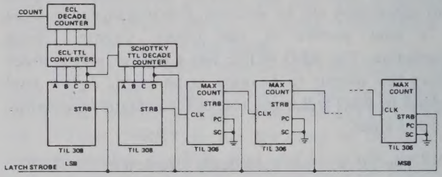

COUNT
ECL DECADE COUNTER
ECL TTL CONVERTER
SCHOTTKY TTL DECADE COUNTER
A B C D
STRB
TIL 308
LSB
A B C D
STRB
TIL 308
MAX COUNT
STRB
CLK
PC
SC
TIL 306
MAX COUNT
STRB
CLK
PC
SC
TIL 306
MAX COUNT
CLK
STRB
PC
SC
TIL 306
MSB
LATCH STROBE

FIGURE 7. Nine Digit Counter

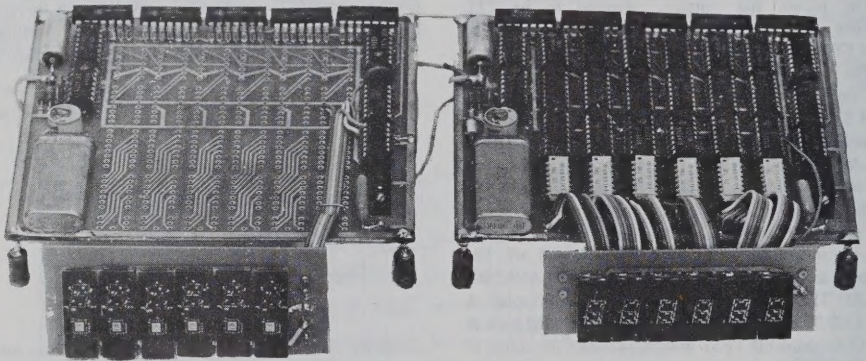


FIGURE 8. Two Counters with Identical Performance. Counter (A) Uses TIL306 Devices; Counter (B) Does not. Note how many less Components are Needed in the Counter Using TIL306 Devices.

Figure 7 is a block diagram representation of a nine-digit readout, consisting of an ECL decade counter with a TIL308 display and a Schottky TTL decade counter with a TIL308 display, as just described, and seven TIL306 devices. Part count is minimal, and the complexity of the PC Board is minimized.

Figure 8 is a photo of two counters with identical performance illustrating the difference in component count between a conventional counter consisting of SN7490, SN7475, and SN7447 TTL integrated circuits, resistors, with a display using TIL302 devices, and a counter using TIL306 devices. Both counters are specified to operate up to 15 MHz using a six digit readout. The counter using TIL306 devices shows a big empty surface in the middle of the board and considerably fewer interconnects to the display. The cost savings resulting from using such a counter are quite obvious.

Figure 9 is a photo of a 100 MHz counter using seven TIL306 devices and two TIL308 devices. A compact assembly technique reduced the total size.

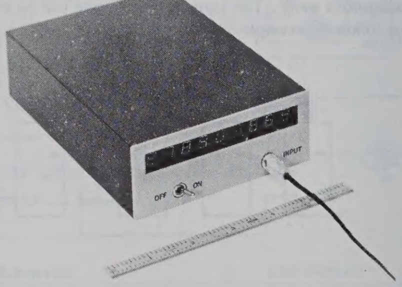

INPUT
OFF
ON

FIGURE 9. A Portable 100 MHz Counter Using Seven TIL306 Devices.

Figure 10 shows all of the basic circuit boards and components used in the counter shown in Figure 9 and shown schematically in Figure 12. The upper board is timebase. The center board is control. The bottom board is counter and display.

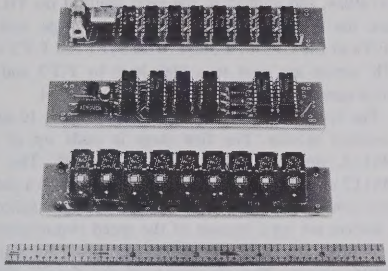


FIGURE 10. The Three Basic Circuit Boards of the Portable Counter.

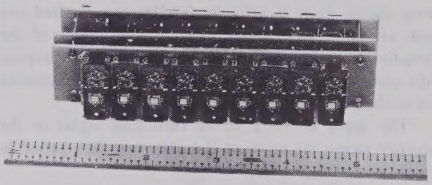


FIGURE 11. The Three Basic Circuit Boards Fastened Together into A Compact unit for high Density Component

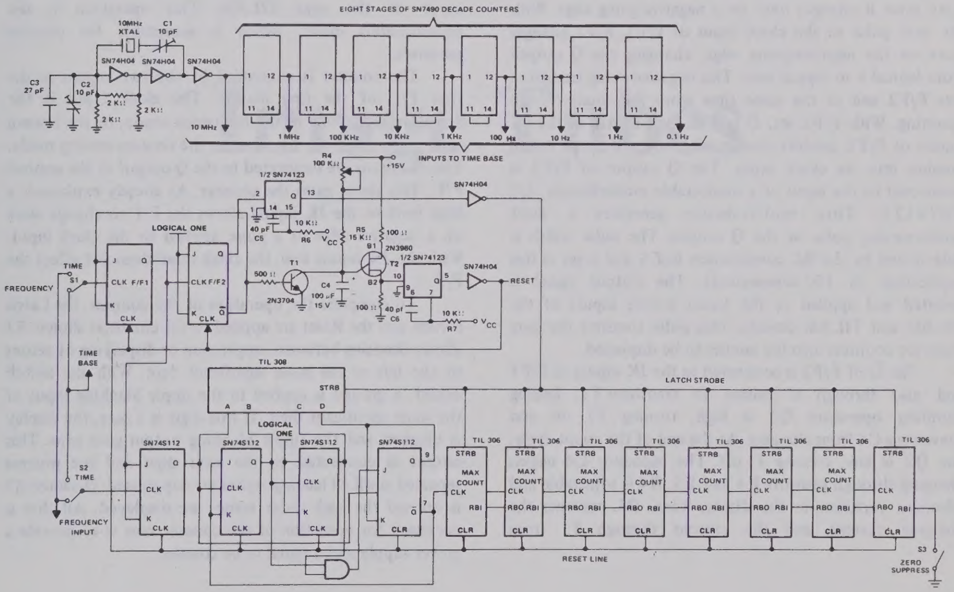

EIGHT STAGES OF SN7490 DECADE COUNTERS
10MHz XTAL
C1 10 pF
SN74H04
SN74H04
SN74H04
C3 27 pF
C2 10 pF
2 KΩ
2 KΩ
2 KΩ
10 MHz
1 MHz
100 KHz
10 KHz
1 KHz
100 Hz
10 Hz
1 Hz
0.1 Hz
INPUTS TO TIME BASE
R4 100 KΩ
+15V
1/2 SN74123
SN74H04
LOGICAL ONE
40 pF C5
10 KΩ R6
VCC
R5 15 KΩ
100 Ω
Q1 2N3960
1/2 SN74123
T2
SN74H04
RESET
TIME
S1
FREQUENCY
CLK F/F1
CLK F/F2
T1
500 Ω
2N3704
C4 100 μF 15 V
100 Ω
40 pf C6
10 KΩ R7
VCC
TIME BASE
TIL 308
STRB
LATCH STROBE
LOGICAL ONE
SN74S112
SN74S112
SN74S112
SN74S112
S2 TIME
FREQUENCY INPUT
TIL 306
STRB
MAX COUNT
CLK
RBI
RBO
CLR
RESET LINE
S3
ZERO SUPPRESS

FIGURE 12. Schematic of A Frequency and Time Counter

Figure 11 shows the assembly technique for high density component packing. The total size is 1.2 inches high, 1.2 inches deep and 4.25 inches wide. This counter can be incorporated in a lightweight and portable instrument. Total power dissipation is 9 watts.

Figure 12 shows a complete schematic of a frequency and time counter incorporating the 100 MHz stage shown in Figure 5 and seven TIL306 devices. This counter is capable of measuring frequencies up to 100 MHz and time with 10 nanosecond resolution. Again minimum part count and simplicity have been the major objectives. The unit is universal and the counter can be expanded into other functions by adding circuits to the basic building block.

The counter has three main functional sections: timebase, control, and counter.

The top part of Figure 12 is the time base. A 10 MHz oscillator is formed using two SN74H04 TTL high speed inverters. The output is coupled through a third inverter to isolate the oscillator from the rest of the circuit. Capacitor C1 is a coarse adjust and capacitor C2 is a fine adjust. C2 should be a piston capacitor to allow finer resolution during adjustment. For more accurate requirements, a separate oscillator in a temperature-controlled oven with AGC circuitry can replace this circuit. The output of the oscillator is fed into a divider chain consisting of eight SN7490 decade dividers. Timing signals from 10 MHz to 0.1 Hz are generated and switch selectable as the time base. In the middle of the schematic in Figure 10 is the control circuit. The purpose of the control circuit is to gate the counter, and to generate latch strobe, and reset signals.

The input of F/F1 is the time base signal in the frequency measuring mode or the unknown time period in the time measuring mode.

With all circuits reset, the $\overline{Q}$ output of F/F2 holds a high level at the JK inputs of F/F1. With a pulse coming into the F/F1, Q of F/F1 changes from 0 to 1 on the negative-going edge. This 1 is applied to the first stage of the counter, allowing it to count. F/F2 does not change state since it changes only on a negative-going edge. With the next pulse to the clock input of F/F1, F/F1 changes state on the negative-going edge, changing the Q output from logical 1 to logical zero. This negative-going transition sets F/F2 and at the same time stops the counter from counting. With F/F2 set, $\overline{Q}$ of F/F2 is a 0. A 0 at the JK inputs of F/F1 inhibits change with any additional pulses coming into its clock input. The Q output of F/F2 is connected to the input of a monostable multivibrator, 1/2 SN74123. This multivibrator generates a short positive-going pulse at the Q output. The pulse width is determined by the RC combination R6C5 and is set in this application to 150 nanoseconds. The output signal is inverted and applied to the Latch Strobe inputs of the TIL306 and TIL308 devices. This pulse transfers the data from the counters into the latches to be displayed.

The $\overline{Q}$ of F/F2 is connected to the JK inputs of F/F1 and also through a resistor to transistor T1. During counting operation $\overline{Q}2$ is high, turning T1 on and preventing C4 from charging. At the end of the count cycle, the $\overline{Q}2$ is low, turning T1 off. The capacitor C4 begins charging through resistors R4 and R5. R4 is adjustable and allows a variation in the display time. R5 prevents the charging current and the current through T1 from exceeding 1 mA when R4 is turned to zero. Once the charge across C4 reaches the firing potential of the unijunction, T2, the unijunction generates a positive pulse at Base 2, which is coupled into the monostable multivibrator, SN74123. The positive pulse determined by R7C6 150 nanoseconds wide is inverted by an inverter, 1/6 of SN74H04, and applied to the reset input of the TIL306 devices, the four F/Fs of the first counter stage, and the two F/Fs in the control section. With F/F1 and F/F2 reset the JK inputs are reset to a high level by F/F2 and the circuit is again ready to handle the incoming signal.

The bottom part of the schematic in Figure 10 shows the counter section. The first stage is made up of two SN74S112, one SN74S11, and one TIL308. The two SN74S112 circuits and one SN74S11 circuit form a decade counter consisting of four flip-flops and one gate. Schottky TTL devices are used because of the speed requirement. If only 70 MHz are required, this circuit could be a single SN74196 circuit. The $\overline{Q}$ output of the fourth F/F is connected to the clock input of the first TIL306. The maximum count of the TIL306 is connected to the clock input of the next TIL306. This operation is the asynchronous mode, which is acceptable for counter purposes.

The counter is controlled by the two inputs to the first F/F of the first decade. The clock input is the unknown frequency in the frequency mode, or the known time pulses from the time base in the time-measuring mode. The JK inputs are connected to the Q output of the control F/F. This signal gates the counter. As already explained, a high level to the JK inputs allows the F/F to change state on a negative edge of a pulse applied to the clock input. With the JK inputs low, the clock input does not affect the F/F.

To complete the operation of the counter, the Latch Strobe and the Reset are applied to the circuit as shown. S3 allows choosing between suppression or displaying of zeroes to the left of the most significant digit. With the switch closed, a ground is applied to the ripple blanking input of the most significant digit. If this digit is a zero, the display is blanked and the ripple blanking output goes zero. This output is connected to the next digit and the process repeated until all leading zeroes are suppressed. If switch S3 is opened the high order zeroes are displayed. All that is necessary for operation of the counter now is to provide a power supply and a signal to be counted.

Image Tubes

IMAGE TUBES
QUICK REFERENCE GUIDE

DEVICE	LIMITING RESOLUTION	SENSITIVITY @ $\lambda = 0.7\ \mu m$	IMAGE RETENTION		DARK CURRENT	FEATURES
	MIN TV LINES	MIN mA/W	MAX %	@ SIGNAL nA	MAX nA	
VID1801	350	450	15	100	10	2/3-inch-diameter camera tube for high-quality color, monochromatic, and portable systems
VID1802	325	450	25	100	15	Low-cost 2/3-inch image tube with high sensitivity for portable surveillance systems
VID2501	600	450	15	200	10	1.0-inch-diameter silicon diode array tube offering high picture quality for all monochromatic CCTV systems
VID2502	500	450	25	200	20	Low-cost 1.0-inch-diameter image tube with high sensitivity for monochromatic applications

TIVICON †

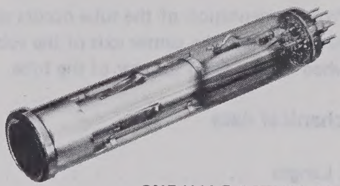
TYPES VID1801, VID1802
SILICON-DIODE-ARRAY IMAGE TUBES

features

- Sensitivity Higher than Vidicon or Lead Oxide Tubes . . . 450 mA/W at Peak λ
- Extremely Broad Spectral Sensitivity Range Making the Tube Suitable for Visible and Near-Infrared Applications
- No Burning of Light-Sensing Surface for High Light Levels ($\leqslant 6 \times 10^7$ lm/ft^2)

applications

- Color Capability for Closed-Circuit and Educational Television
- Monochrome Closed-Circuit Television
- Videophone
- Portable Industrial Television Equipment
- Hospital Surveillance
- Industrial and Military Applications



ONE-HALF ACTUAL SIZE

description

The VID1801 and VID1802 TIVICON tubes are two-thirds-inch (18-millimeter) silicon-diode-array image tubes utilizing scanning electron optics of the all-magnetic separate-mesh type. The light-sensing surface is a single slice of a silicon crystal containing at least 620,000 diodes per square centimeter, with 360,000 diodes within a standard 0.260-inch X 0.346-inch (6.6-mm X 8.8-mm) beam-scanned raster. The use of silicon material as the light-sensing surface provides a spectral response from 0.35 to 1.1 micrometers with low dark current and low image-retention properties.

The VID1801 and VID1802 are standard TIVICON devices for industrial and commerical applications. Versions of both can be provided which have the same performance with additional environmental qualifications for military applications.

electrical data

Heater Voltage, AC or DC	6.3 V ± 10%
Heater Current at 6.3 V (Nominal)	95 mA
Nominal Direct Interelectrode Capacitance, Target to Other Electrodes (See Note 1)	3 pF
Focusing Method (See Note 2)	magnetic
Deflection Method (See Note 2)	magnetic

optical data

Spectral Response (See Figure 2)	0.35 to 1.1 μm
Target-to-Front-Plate Distance (See Figure 9)	0.070 ± 0.010 in 1.78 ± 0.25 mm
Target-to-Face-Plate Distance (See Figure 9)	0.020 ± 0.007 in 0.51 ± 0.18 mm
Faceplate Thickness (See Figure 9)	0.050 ± 0.003 in 1.27 ± 0.08 mm
Faceplate Index of Refraction at 0.5893 μm	1.487

NOTES: 1. This capacitance will increase as the tube is inserted into the focus and deflection coil assemblies.
2. Defelction and focusing alignment coils: Sanyo R-W-1861 or Mullard KV-12 or equivalent.

†Trademark of Texas Instruments Incorporated.

TENTATIVE DATA SHEET

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

target

Scanned Area	0.260 in X 0.346 in 6.6 mm X 8.8 mm
Maximum Useful Diagonal	0.435 in 11.05 mm

Orientation of Raster:

Proper orientation of the tube occurs when the horizontal scan axis, defined as the axis through the index (gap in pin circle) and the center axis of the tube, is parallel to the horizontal deflection plane with the index at 9 o'clock when viewed from the rear of the tube.

general mechanical data

Overall Length	3.935 ± 0.035 in 99.95 ± 0.89 mm
Greatest Diameter	0.778 ± 0.005 in 19.76 ± 0.13 mm
Base	7-Pin Miniature Small Button Ditetrar
Bulb	E7-1
Socket	Amphenol 78-7P (See Notes 3 and 4)
Deflection and Focusing Alignment Coils	See Note 5
Weight (approximate)	0.77 oz 21.8 g
Detailed Outline Dimensions	See Figure 9
Operating Position	Any

absolute maximum ratings at 25° C faceplate temperature (unless otherwise noted), see notes 6 and 7

Target Voltage	10 V
Grid-4 Voltage	350 V
Grid-3 Voltage (See Note 8)	Grid 4 Voltage
Grid-2 Voltage	350 V
Grid-1 Voltage	−150 V
Heater-Cathode Peak Voltage Range	−125 V to 10 V
Faceplate Illumination (See Note 9)	6 X 10^7 lm/ft^2 6 X 10^8 lux 3 X 10^7 W/m^2
Operating Temperature Range (See Note 10)	−10°C to 100°C
Storage Temperature Range	−54°C to 200°C

NOTES:
3. Manufactured by Amphenol, 2801 South 25th Ave., Broadview, Illinois 60153.
4. Center hole requires enlargement.
5. For dimensions and approximate position of these coils, see Figure 10.
6. The maximum ratings in the tabulated data are established in accordance with the following definition for rating electron devices: absolute maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.
7. All voltages with the exception of heater voltage are with respect to the cathode when the cathode is unblanked.
8. Grid-3 voltage must be less than grid-4 voltage. The recommended ratio is between 0.8 and 0.9 to 1.
9. TIVICON image tubes can stand the image of the sun on the light-sensing layer without damage.
10. The dark current of silicon-diode arrays doubles with each 10°C increase in array temperature. Consequently, although no damage will occur from operating the tube at 100°C, the obtaining of a usable picture cannot be guaranteed at that temperature.

recommended operating conditions at 25°C faceplate temperature, see note 7

Grid-4 Voltage	350 V
Grid-3 Voltage (See Note 8)	300 V
Grid-2 Voltage	300 V
Grid-1 Voltage for Picture Cutoff	−40 to −75 V
Target Voltage	10 V
Peak-to-Peak Blanking Voltage:	
Applied to Grid 1	−75 V
Applied to Cathode	20 V
Field Strength at Center of Focus Coil	55 ± 5 Gauss
Field Strength of Adjustable Alignment Coil	0 to 4 Gauss
Focusing Coil Current	136 mA
Peak-to-Peak Deflecting Coil Alignment Current:	
Horizontal	135 mA
Vertical	20 mA
Tube and Coil Positioning	See Figure 10

operating characteristics at 25°C faceplate temperature and recommended operating conditions

PARAMETER		TEST CONDITIONS	VID1801			VID1802			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Sensitivity *Signal Current*	Monochromatic Light	λ = 0.7 μm	450			450			mA/W
	Unfiltered Light from Tungsten Source	Color temperature = 2854 K, Faceplate illumination = 0.1 lm/ft^2		6300 *395*			6300 *395*		μA/lm *nA*
	Visible Light	Color temperature = 2854 K, See Note 11		1180 *74*			1180 *74*		μA/lm *nA*
	Infrared Light	See Note 12		*37*			*37*		*nA*
Dark Current					10			15	nA
Lag	After 33 ms or third field	Signal current = 100 nA			15%			25%	
	After 50 ms or fourth field				10%			20%	
Limiting Resolution		See Note 13	350			325			TV lines
Number of Linear Gray Scale Steps Reproduced on Resolution Chart			10			10			steps
Nonuniformity (See Note 14)					20%			20%	
Transfer Characteristic, γ		Signal current = 4 nA to 500 nA		1.0			1.0		

NOTES: 7. All voltages with the exception of heater voltage are with respect to the cathode when the cathode is unblanked.

8. Grid-3 voltage must be less than grid-4 voltage. The recommended ratio is between 0.8 and 0.9 to 1.

11. With a tungsten light source of the specified color temperature, an infrared-absorbing filter (Schoot KG-3, 5 mm thick, available from Fish Shurman Corp., New Rochelle, N.Y., or equivalent) is interposed between the light source and the tube faceplate. Illumination on the IR filter is 0.1 lm/ft^2.

12. With a tungsten light source at a color temperature of 2854 K, an infrared-transmitting filter (Corning CS-7-56, available from Corning Glass Works, Corning, N.Y., or equivalent) is interposed between the light source and the tube faceplate. Illumination on the IR filter is 0.1 lm/ft^2.

13. Resolution is measured with an uncompensated video amplifier with response that is flat within ± 1 dB to 10 MHz. Limiting resolution is defined as the TV-line number at which the amplitude response is 5% of the response at some very low TV-line number. TV-line numbers are determined by the number of equal width black and white lines which will fit into the physical height of the image focused on the camera-tube faceplate. Resolution measurements are made on a 4-by-3 aspect ratio with a 0.435-inch (11.05-mm) diagonal dimension.

14. Nonuniformity is the deviation within the scanned area expressed as a percentage of the peak video signal.

TYPES VID1801, VID1802
SILICON-DIODE-ARRAY IMAGE TUBES

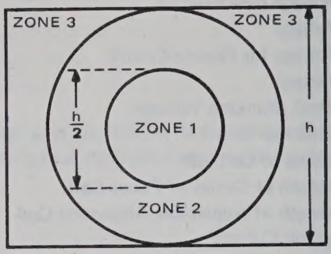
defect definitions

The quality of a silicon-diode-array tube is a function not only of the size and the number of white and black defects which appear on the scanned area, but also of the location of these defects. Three nonoverlapping zones are defined for defect location as shown in Figure 1.

A blemish is defined as a point-type black or white defect within the image that produces a spurious signal that exceeds or equals 10% of an otherwise uniform signal. An area defect within the image produces a spurious signal that exceeds or equals 3% of an otherwise uniform signal.

Blemish and area-type-defect widths are measured in equivalent TV scan lines in a 525-scan-line system, with a raster geometry of 0.260 inch by 0.346 inch (6.6 mm X 8.8 mm) using a uniform signal of 150 nA at a faceplate temperature of 25°C.

The table below shows the maximum number of defects allowed according to size and location for each of the tube types.



DEFECT ZONES
Zone 1 is 15% of area.
Zone 2 is 45% of area.
Zone 3 is 40% of area.

FIGURE 1

TUBE TYPE	DEFECT SIZE	MAXIMUM NUMBER OF DEFECTS		
		ZONE 1	ZONE 2	ZONE 3
VID1801	1 TV line or less†			
	Over 1 TV line	1	2	2
	Over 4 TV lines	0	1	2
	Over 6 TV lines	0	0	1
	Over 9 TV lines	0	0	0
VID1802	1 TV line or less†			
	Over 1 TV line	1	3	4
	Over 4 TV lines	0	1	2
	Over 6 TV lines	0	0	1
	Over 9 TV lines	0	0	1
	Over 16 TV lines	0	0	0

†Defects of this size are not counted unless clustered to produce an area-type defect.

TYPICAL CHARACTERISTICS

SPECTRAL RESPONSE CHARACTERISTICS

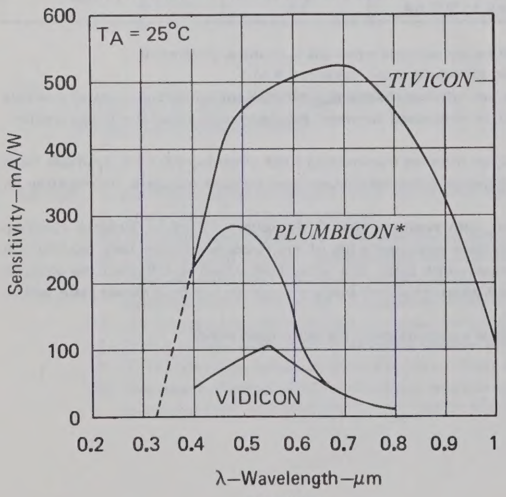


FIGURE 2

*Registered trademark of North American Philips Corporation

SOURCES:

Vidicon curve is from RCA type 4503A data sheet dated 8-68.

Plumbicon curve is from an article entitled "New Plumbicon TV Camera Pickup Tubes" by R.S. Levitt, Ampex Electro-Optics Corp., published in "Society of Motion Picture and Television Engineers," Vol. 79, No. 2, February 1970.

TYPICAL CHARACTERISTICS

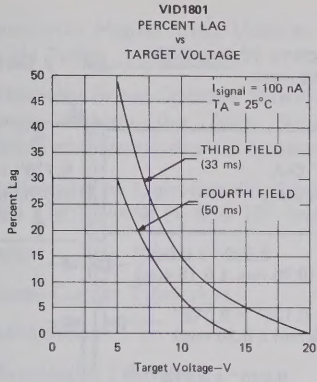


FIGURE 3

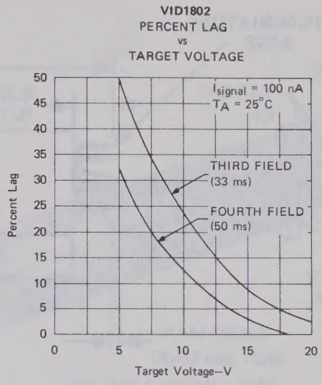


FIGURE 4

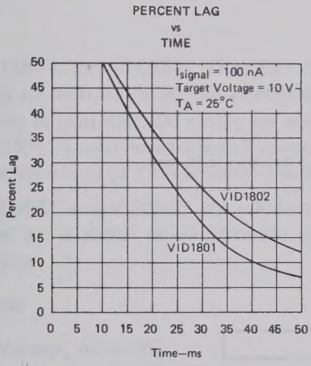


FIGURE 5

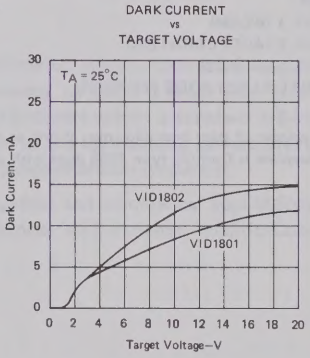


FIGURE 6

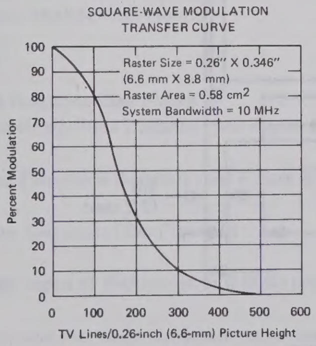


FIGURE 7

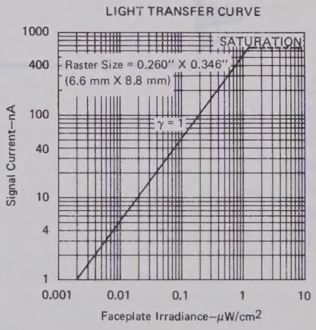
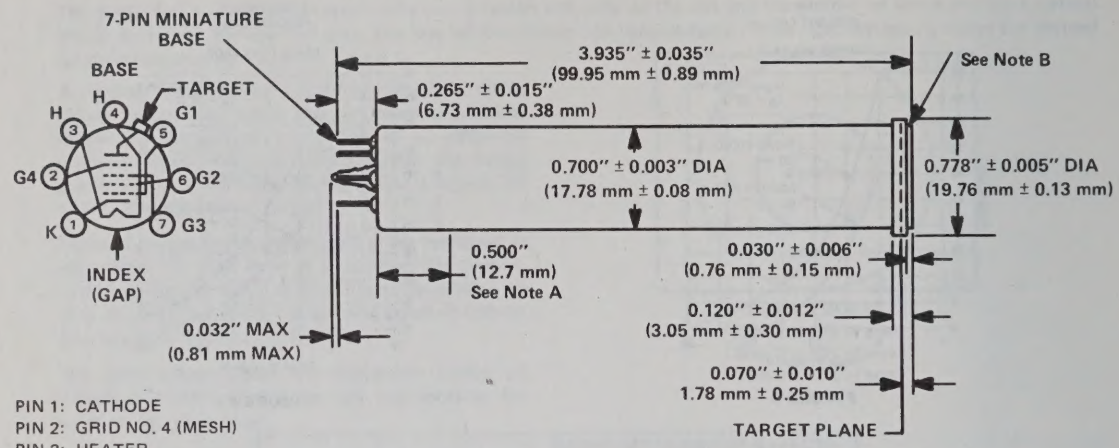


FIGURE 8

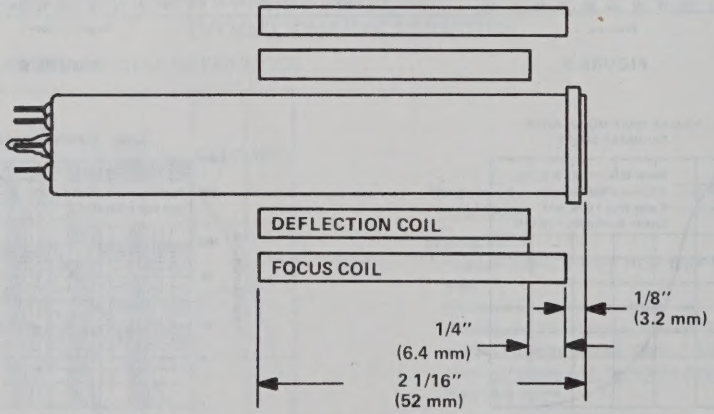
MECHANICAL DATA


7-PIN MINIATURE BASE
BASE
H
H
TARGET
G1
3
4
5
G4
2
6
G2
K
1
7
G3
INDEX (GAP)
3.935" ± 0.035"
(99.95 mm ± 0.89 mm)
See Note B
0.265" ± 0.015"
(6.73 mm ± 0.38 mm)
0.700" ± 0.003" DIA
(17.78 mm ± 0.08 mm)
0.778" ± 0.005" DIA
(19.76 mm ± 0.13 mm)
0.500"
(12.7 mm)
See Note A
0.030" ± 0.006"
(0.76 mm ± 0.15 mm)
0.120" ± 0.012"
(3.05 mm ± 0.30 mm)
0.032" MAX
(0.81 mm MAX)
0.070" ± 0.010"
1.78 mm ± 0.25 mm
TARGET PLANE

PIN 1: CATHODE
PIN 2: GRID NO. 4 (MESH)
PIN 3: HEATER
PIN 4: HEATER
PIN 5: GRID NO. 1 (BEAM)
PIN 6: GRID NO. 2 (ACCELERATOR)
PIN 7: GRID NO. 3 (FOCUS)
FLANGE: SIGNAL ELECTRODE (TARGET)

NOTES: A. Diameter of tube near ends may shrink as required for sealing.
B. Faceplate is Corning type 7056 glass with a thickness of 0.050" ± 0.003" (1.27 mm ± 0.08 mm).

PHYSICAL DIMENSIONS
FIGURE 9


DEFLECTION COIL
FOCUS COIL
1/8"
(3.2 mm)
1/4"
(6.4 mm)
2 1/16"
(52 mm)

APPROXIMATE COIL LOCATIONS
SANYO R-W-1861 YOKE
FIGURE 10

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIM
IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBL

TIVICON†

TYPES VID2501, VID2502
SILICON-DIODE-ARRAY IMAGE TUBES

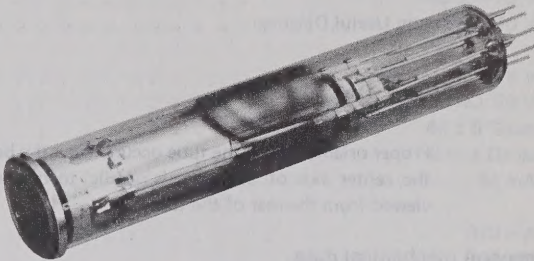
TYPES VID2501, VID2502
BULLETIN NO. DL-S 7221691, MARCH 1972

features

- Sensitivity Higher than Vidicon or Lead Oxide Tubes . . . 450 mA/W at Peak λ
- Extremely Broad Spectral Sensitivity Range Making the Tube Suitable for Visible and Near-Infrared Applications.
- No Burning to Light-Sensing Surface for High Light Levels (≤ 6 X 10^7 lm/ft^2)

applications

- Closed-Circuit Television
- Videophone
- Educational Television
- Hospital Surveillance
- Industrial and Military Applications.



ONE-HALF ACTUAL SIZE

description

The VID2501 and VID2502 TIVICON tubes are one-inch (25.4-millimeter) silicon-diode-array image tubes utilizing scanning electron optics of the all-magnetic 8507 type. The light-sensing surface is a single slice of a silicon crystal containing at least 620,000 diodes per square centimeter, with 750,000 diodes within a standard 3/8-inch X 1/2-inch (9.5-mm X 12.7-mm) beam-scanned raster. The use of silicon material as the light-sensing surface provides a spectral response from 0.35 to 1.1 micrometers with low dark current and low image-retention properties.

The VID2501 and VID2502 are standard TIVICON devices for industrial and commerical applications. Versions of both can be provided which have the same performance with additional environmental qualifications for military applications.

electrical data

Heater Voltage, AC or DC	6.3 V ± 10%
Heater Current at 6.3 V (See Note 1)	0.3 A ± 10%
Nominal Direct Interelectrode Capacitance, Target to Other Electrodes (See Note 2)	4.6 pF
Focusing Method (See Note 3)	magnetic
Deflection Method (See Note 3)	magnetic

optical data

Spectral Response (See Figure 2)	0.35 to 1.1 μm
Target-to-Front-Plate Distance (See Figure 8)	0.073 ± 0.010 in 1.85 ± 0.25 mm
Target-to-Face-Plate Distance (See Figure 8)	0.023 ± 0.007 in 0.58 ± 0.18 mm
Faceplate Thickness (See Figure 8)	0.050 ± 0.003 in 1.27 ± 0.08 mm
Faceplate Index of Refraction at 0.5893 μm	1.487

NOTES:
1. Cathodes with heater currents of 95 mA are available on special request.
2. This capacitance will increase as the tube is inserted into the focus and deflection coil assemblies.
3. Deflection and focusing alignment coils: VYLFA 857 from Cleveland Electronics Inc., 200 Highland Road, Twinsburg, Ohio 44087 (or equivalent).

†Trademark of Texas Instruments Incorporated

TENTATIVE DATA SHEET

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

target

Scanned Area	3/8 in X 1/2 in 9.5 mm X 12.7 mm
Maximum Useful Diagonal	0.62 in 15.75 mm

Orientation of Raster:

Proper orientation of the tube occurs when the horizontal scan axis, defined as the axis given by the short pin and the center axis of the tube, is parallel to the horizontal deflection plane with the short pin at 9 o'clock when viewed from the rear of the tube.

general mechanical data

Overall Length	6.250 ± 0.125 in 158.75 ± 3.18 mm
Greatest Diameter	1.125 ± 0.010 in 28.58 ± 0.25 mm
Base	Small Button Ditetrar (JEDEC E8-11)
Bulb	T8
Socket	Cinch No. 8 VT (See Note 4) or equivalent
Deflection and Focusing Alignment Coils	See Note 5
Weight (approximate)	2.3 oz 65.2 g
Detailed Outline Dimensions	See Figure 8
Operating Position	Any

absolute maximum ratings at 25°C faceplate temperature (unless otherwise noted), see notes 6 and 7

Target Voltage	10 V
Grid-4 Voltage	350 V
Grid-3 Voltage (See Note 8)	Grid 4 Voltage
Grid-2 Voltage	350 V
Grid-1 Voltage	−150 V
Heater-Cathode Peak Voltage Range	−125 V to 10 V
Faceplate Illumination (See Note 9)	6 X 10^7 lm/ft^2 6 X 10^8 lux 3 X 10^7 W/m^2
Operating Temperature Range (See Note 10)	−10°C to 100°C
Storage Temperature Range	−54°C to 200°C

NOTES:
4. Manufactured by Cinch Manufacturing Company, 1501 Morse Avenue, Elk Grove Village, Illinois 6007.
5. For dimensions and approximate position of these coils, see Figure 9.
6. The maximum ratings in the tabulated data are established in accordance with the following definition for rating electron devices: absolute maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.
7. All voltages with the exception of heater voltage are with respect to the cathode when the cathode is unblanked.
8. Grid-3 voltage must be less than grid-4 voltage. The recommended ratio is between 0.8 and 0.9 to 1.
9. TIVICON image tubes can stand the image of the sun on the light-sensing layer without damage.
10. The dark current of silicon-diode-arrays doubles with each 10°C increase in array temperature. Consequently, although no damage will occur from operating the tube at 100°C, the obtaining of a usable picture cannot be guaranteed at that temperature.

recommended operating conditions at 25°C faceplate temperature, see note 7

Grid-4 Voltage	350 V
Grid-3 Voltage (See Note 8)	290 V
Grid-2 Voltage	300 V
Grid-1 Voltage for Picture Cutoff	−40 to −75 V
Target Voltage	10 V
Peak-to-Peak Blanking Voltage:	
Applied to Grid 1	−75 V
Applied to Cathode	20 V
Field Strength at Center of Focus Coil	40 ± 5 Gauss
Field Strength of Adjustable Alignment Coil	0 to 4 Gauss
Focusing Coil Current	54 mA
Peak-to-Peak Deflecting Coil Alignment Current:	
Horizontal	370 mA
Vertical	36 mA
Tube and Coil Positioning	See Figure 9

operating characteristics at 25°C faceplate temperature and recommended operating conditions

PARAMETER		TEST CONDITIONS	VID2501			VID2502			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Sensitivity *Signal Current*	Monochromatic Light	λ = 0.7 μm	450			450			mA/W
	Unfiltered Light from Tungsten Source	Color temperature = 2854 K, Faceplate illumination = 0.1 lm/ft^2		6300 *820*			6300 *820*		μA/lm *nA*
	Visible Light	Color temperature = 2854 K, See Note 11		1180 *153*			1180 *153*		μA/lm *nA*
	Infrared Light	See Note 12		*77*			*77*		*nA*
Dark Current					10			20	nA
Lag	After 33 ms or third field	Signal current = 200 nA			15%			25%	
	After 50 ms or fourth field				10%			20%	
Limiting Resolution		See Note 13	600			500			TV lines
Number of Linear Gray Scale Steps Reproduced on Resolution Chart			10			10			steps
Nonuniformity (See Note 14)					20%			20%	
Transfer Characteristic, γ		Signal current = 4 nA to 500 nA		1.0			1.0		

NOTES:

7. All voltages with the exception of heater voltage are with respect to the cathode when the cathode is unblanked.
8. Grid-3 voltage must be less than grid-4 voltage. The recommended ratio is between 0.8 and 0.9 to 1.
11. With a tungsten light source of the specified color temperature, an infrared-absorbing filter (Schoot KG-3, 5 mm thick, available from Fish Shurman Corp., New Rochelle, N.Y., or equivalent) is interposed between the light source and the tube faceplate. Illumination on the IR filter is 0.1 lm/ft^2.
12. With a tungsten light source at a color temperature of 2854 K, an infrared-transmitting filter (Corning CS-7-56, available from Corning Glass Works, Corning, N.Y., or equivalent) is interposed between the light source and the tube faceplate. Illumination on the IR filter is 0.1 lm/ft^2.
13. Resolution is measured with an uncompensated video amplifier with response that is flat within ± 1 dB to 10 MHz. Limiting resolution is defined as the TV-line number at which the amplitude response is 5% of the response at some very low TV-line number. TV-line numbers are determined by the number of equal width black and white lines which will fit into the physical height of the image focused on the camera-tube faceplate. Resolution measurements are made on a 4-by-3 aspect ratio with a 0.62-inch (15.75-mm) diagonal dimension.
14. Nonuniformity is the deviation within the scanned area expressed as a percentage of the peak video signal.

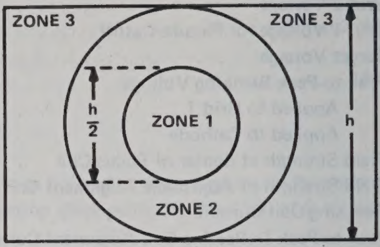
defect definitions

The quality of a silicon-diode-array tube is a function not only of the size and the number of white and black defects which appear on the scanned area, but also of the location of these defects. Three nonoverlapping zones are defined for defect location as shown in Figure 1.

A blemish is defined as a point-type black or white defect within the image that produces a spurious signal that exceeds or equals 10% of an otherwise uniform signal. An area defect within the image produces a spurious signal that exceeds or equals 3% of an otherwise uniform signal.

Blemish and area-type-defect widths are measured in equivalent TV scan lines in a 525-scan-line system, with a raster geometry of 3/8 inch by 1/2 inch (9.5 mm X 12.7 mm) using a uniform signal of 300 nA at a faceplate temperature of 25°C.

The table below shows the maximum number of defects allowed according to size and location for each of the tube types.



DEFECT ZONES
Zone 1 is 15% of area.
Zone 2 is 45% of area.
Zone 3 is 40% of area.

FIGURE 1

TUBE TYPE	DEFECT SIZE	MAXIMUM NUMBER OF DEFECTS		
		ZONE 1	ZONE 2	ZONE 3
VID2501	1 TV line or less†			
	Over 1 TV line	1	4	5
	Over 4 TV lines	0	1	3
	Over 6 TV lines	0	0	0
VID2502	1 TV line or less†			
	Over 1 TV line	2	6	6
	Over 4 TV lines	0	3	3
	Over 6 TV lines	0	0	1
	Over 12 TV lines	0	0	0

†Defects of this size are not counted unless clustered to produce an area-type defect.

TYPICAL CHARACTERISTICS

SPECTRAL RESPONSE CHARACTERISTICS

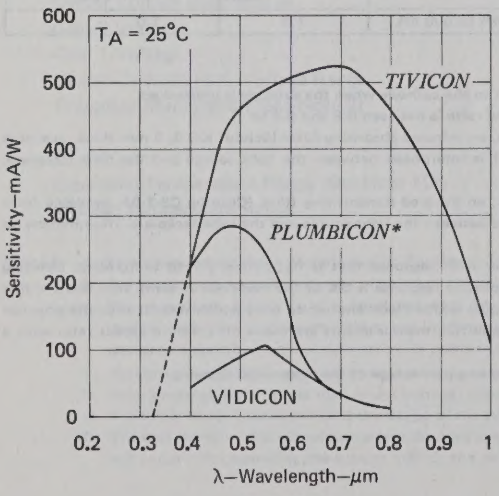


FIGURE 2

*Registered trademark of North American Philips Corporation

SOURCES:

Vidicon curve is from RCA type 4503A data sheet dated 8-68.

Plumbicon curve is from an article entitled "New Plumbicon TV Camera Pickup Tubes" by R.S. Levitt, Ampex Electro-Optics Corp., published in "Society of Motion Picture and Television Engineers," Vol. 79, No. 2, February 1970.

TYPICAL CHARACTERISTICS

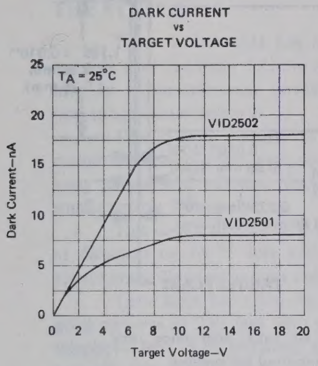


FIGURE 3

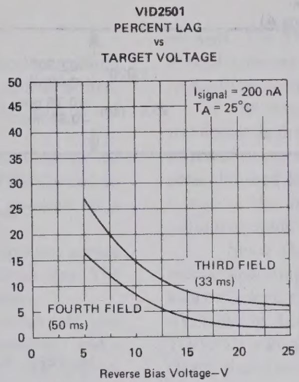


FIGURE 4

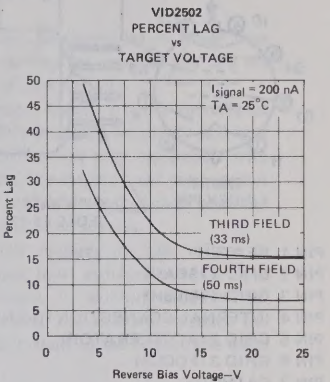


FIGURE 5

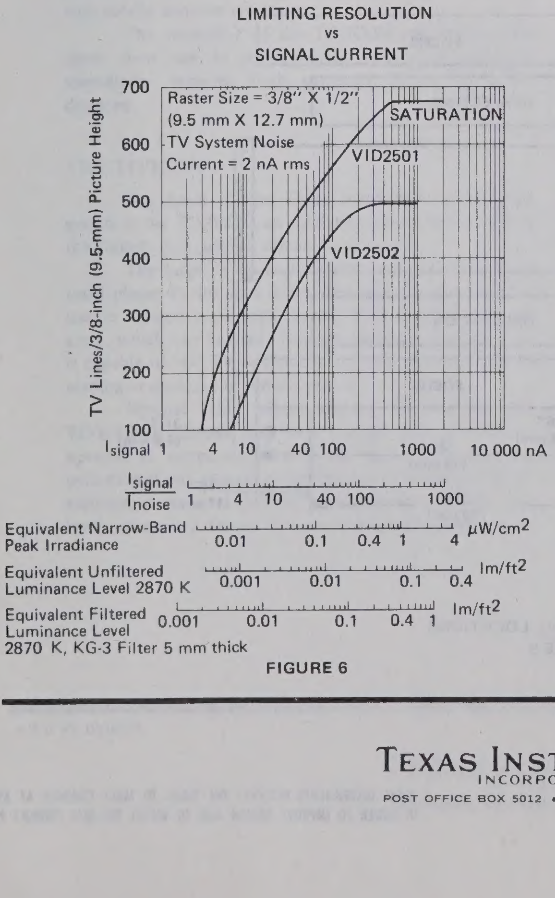


FIGURE 6

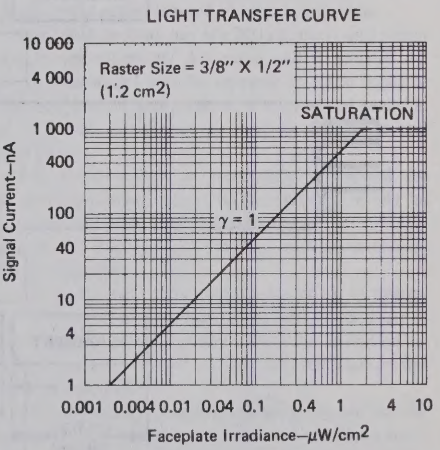
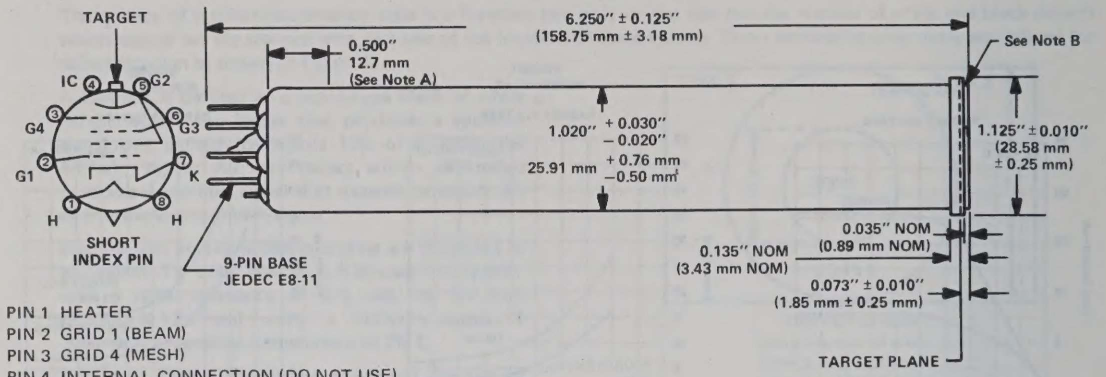


FIGURE 7

TYPES VID2501, VID2502
SILICON–DIODE–ARRAY IMAGE TUBES

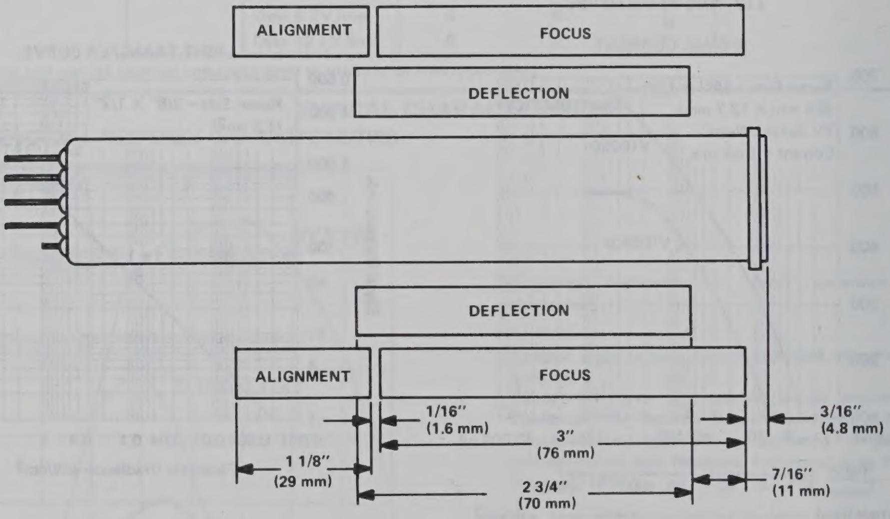
MECHANICAL DATA


TARGET
IC
G2
G4
G3
G1
K
H
H
SHORT INDEX PIN
9-PIN BASE JEDEC E8-11
6.250″ ± 0.125″ (158.75 mm ± 3.18 mm)
0.500″ 12.7 mm (See Note A)
See Note B
1.020″ + 0.030″ − 0.020″
25.91 mm + 0.76 mm −0.50 mm
1.125″ ± 0.010″ (28.58 mm ± 0.25 mm)
0.035″ NOM (0.89 mm NOM)
0.135″ NOM (3.43 mm NOM)
0.073″ ± 0.010″ (1.85 mm ± 0.25 mm)
TARGET PLANE

PIN 1 HEATER
PIN 2 GRID 1 (BEAM)
PIN 3 GRID 4 (MESH)
PIN 4 INTERNAL CONNECTION (DO NOT USE)
PIN 5 GRID 2 (ACCELERATOR)
PIN 6 GRID 3 (FOCUS)
PIN 7 CATHODE
PIN 8 HEATER
SHORT INDEX PIN: INTERNAL CONNECTION (DO NOT USE)
FLANGE: SIGNAL ELECTRODE (TARGET)

NOTES: A. Diameter of tube near ends may shrink as required for sealing.
B. Faceplate is Corning type 7056 glass with a thickness of 0.050″ ± 0.003″ (1.27 mm ± 0.09 mm).

PHYSICAL DIMENSIONS
FIGURE 8


ALIGNMENT
FOCUS
DEFLECTION
DEFLECTION
ALIGNMENT
FOCUS
1/16″ (1.6 mm)
3″ (76 mm)
3/16″ (4.8 mm)
1 1/8″ (29 mm)
2 3/4″ (70 mm)
7/16″ (11 mm)

APPROXIMATE COIL LOCATIONS
FIGURE 9

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

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TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

TELEVISION SURVEILLANCE SYSTEMS

THE SYSTEM

Texas Instruments has taken the perfect gallium arsenide emitter-silicon detector match and combined them into an active television surveillance system capable of operating in total darkness.

The system consists of a self-contained closed circuit television camera equipped with a TIVICON and an array of six 200 milliwatt GaAs emitters powered by a small portable DC supply.

This equipment will give good high contrast images at distances up to 75 feet with a f/1.4 25mm lens. The approximate illuminator cone angle is 23 degrees.

Tests have been run on a system which will give good pictures at 250 feet with a larger illuminator and a telephoto lens. For distances greater than this, gallium arsenide illumination from the camera site becomes very bulky and expensive. However, in many applications, the illuminator can be placed closer to the subject than the camera for better brightness and economy.

Due to the long lifetime and small site and power consumption of the emitters, it is possible to place a complete active surveillance system in remote or inaccessible places without fear of frequent maintenance.

Coupled with infrared film cameras, the system could be used to spot subjects for permanent recording with totally invisible radiation.

The versatility of the TIVICON and the emitters allow their use in an unlimited variety of television surveillance systems, both presently in use or newly designed.

THE TIVICON

The heart of the Texas Instruments surveillance system is the TIVICON, an infrared sensitive image tube of the vidicon type, using a silicon diode target.

The target is an array of more than half a million small planar diodes on a silicon slice specially processed for use in vidicon type applications. With this high density array, which can be made virtually spot-free, the TIVICON is capable of 900 TV line resolution, enough for document reading or monitoring control panels.

Because the photosensitive material in the TIVICON is silicon rather than a fragile film, it is able to operate at temperatures of –40° to +150°F for long periods without damage or degradation of image quality. In addition, it is not susceptible to damage by very high light levels, nor will it bloom if it must look into intense points of light. The TIVICON also has lower lag or smear than normal vidicons so that it may be used in pan and tilt applications without loss of information.

The most important feature from a surveillance standpoint is the TIVICON's increased sensitivity and near infrared response. TIVICON is not only compatible with presently-used light sources like tungsten and mercury but it also works extremely well with both xenon arcs and gallium arsenide solid-state infrared sources.

Since the TIVICON requires no high voltage or special operating conditions, most standard separate-mesh vidicon cameras will accept it without modification. Available in both commercial and military versions, the TIVICON will allow your system to see farther and more clearly than ever before.

THE GaAs ILLUMINATOR

Producing radiation in the near-infrared (9300Å) where the eye cannot see, gallium arsenide (GaAs) diodes provide dependable, invisible illumination from small, efficient sources.

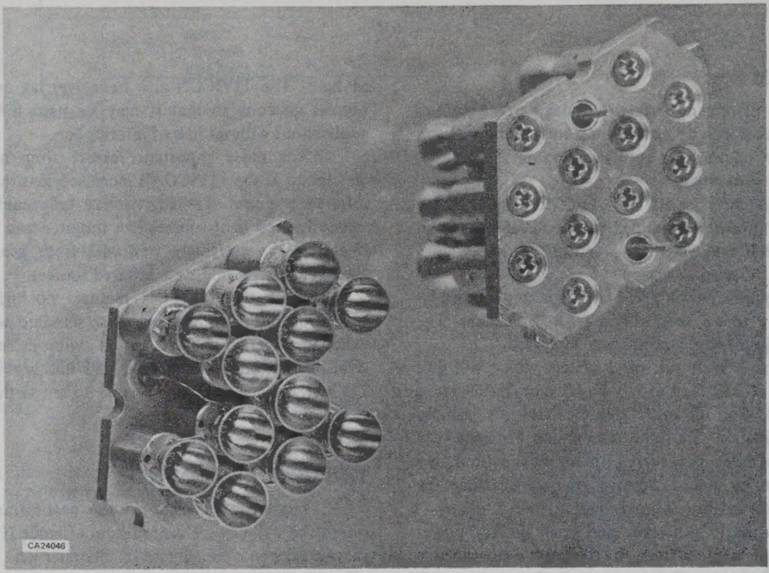
Texas Instruments produces these sources in sizes from tiny microwatt units to the new illuminators with actual continuous radiated powers as high as 400 milliwatts. While the smaller diodes are used mainly in data processing applications, the large units are designed specifically to be used as sources in active infrared surveillance systems.

The most popular size is a 200-milliwatt unit which operates at approximately 1.5 volts and 1 ampere dc. Groups of illuminators may be operated in either series or parallel configuration depending on the nature of available power. Lifetimes of the large emitters exceed several thousand hours.

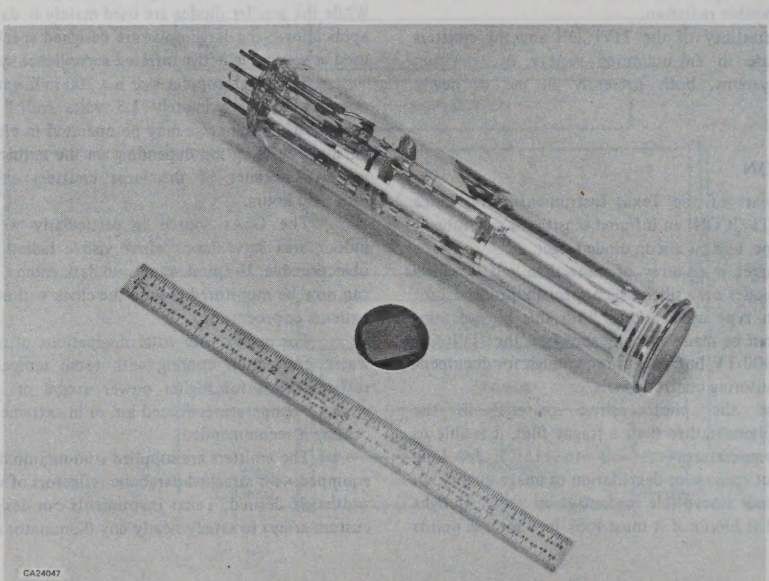
The GaAs source is particularly well-suited for indoor area surveillance where visible radiation would be objectionable. Hospital wards and dark rooms, for instance, can now be monitored around the clock without disturbing patients or processing.

For arrays with total dissipations of up to twenty watts, convection cooling with room temperature air is sufficient but for higher power arrays or operation at elevated temperatures forced air, or in extreme cases, water cooling is recommended.

The emitters are supplied stud-mounted and may be equipped with attached parabolic reflectors of various beam widths. If desired, Texas Instruments can design complete custom arrays to satisfy nearly any illuminator need.



Typical Array of 200 Milliwatt GaAs Emitters



TIVICON Silicon Vidicon and Diode Array

TIVICON IMAGE TUBES

One-Inch (25 MM) TIVICON Image Tube

The Texas Instruments one-inch TIVICON* solid state image pickup tube uniquely combines semiconductor integrated circuit technique with electron tube technology. By combining a wafer of silicon containing 2.4 million photodiodes (620,000/cm^2) with a standard one-inch diameter vidicon electron optic structure, an image pickup tube is produced which has entirely new properties and provides many benefits to the television image tube industry. The spectral response of the TIVICON image tube is unmatched by any other image tube available currently.

The TIVICON image tube, when viewed externally, appears identical to a one-inch vidicon tube except for the metallic appearance of the silicon array behind the tube's faceplate. The electron optics used and voltages normally applied to a TIVICON image tube are those also applied to vidicon tube. The only electrical differences between a vidicon tube and TIVICON image tube are target voltage range and a higher signal current. These are discussed later. Figure 1 shows a cross section of an all-magnetic TIVICON image tube structure. Similarity of the characteristics and requirements of a TIVICON image tube and those of a vidicon tube can be noted. An actual 6.25-inch long TIVICON image tube is pictured in Figure 2, with a typical silicon diode array used in this tube shown separately.

The present TIVICON image tube form is a one-inch diameter vidicon-type using a planar silicon diode array of the type reported by Crowell, Gordon, et al.,[1,2] of Bell Telephone Laboratories as the light sensor rather than an evaporated photoconductive coating.

On the 0.875-inch diameter silicon slice, a 1000 X 750 array of the diodes is scanned in the standard 1/2 X 3/8 inch raster area. The diodes are approximately 5.0 μm in diameter on 12.5 μm centers. The tube utilizes magnetic focus and deflection of the electron beam. The substrate is typically 10 Ω-cm, n-type silicon. The p-type islands are formed by diffusing boron through holes cut in the SiO$_2$ layer by a photolithographic process. A semi-insulating layer is applied for oxide discharging.

TIVICON IMAGE TUBE OPERATION

To understand the operation of the device, visualize the electron beam scanning the diode array portion of the silicon slice. Since the substrate of the target is nominally 10 volts positive relative to cathode, the electron beam will deposit electrons at the diodes, charging them to cathode potential. The diodes will remain charged until the depletion layer capacitance, which is a measure of the diode charge-storing capability, is discharged by light-created minority carriers (holes) or by diode leakage. The holes generated at the light incident surface (as shown in Figure 3) are swept across the depletion region to the diode p-type region and contribute to the leakage current. Recharging of the diode by the electron beam creates the desired video signal at the video amplifier load resistor R$_L$. Since all the holes reaching a diode during a scan time contribute to the discharging of the diode, the signal is proportional to the integrated local photon flux.

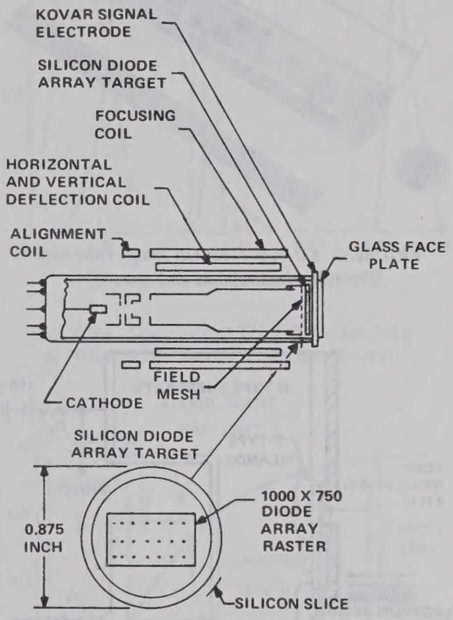

KOVAR SIGNAL ELECTRODE
SILICON DIODE ARRAY TARGET
FOCUSING COIL
HORIZONTAL AND VERTICAL DEFLECTION COIL
ALIGNMENT COIL
GLASS FACE PLATE
FIELD MESH
CATHODE
SILICON DIODE ARRAY TARGET
1000 X 750 DIODE ARRAY RASTER
0.875 INCH
SILICON SLICE

FIGURE 1. Typical Physical Characteristics of a TIVICON Image Tube

For optimum performance of the array a semi-insulating film is deposited over the array during

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* Trademark of Texas Instruments Incorporated

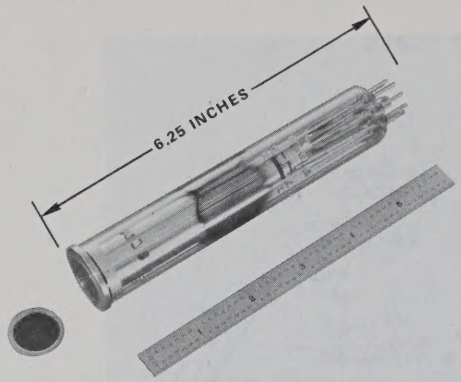

FIGURE 2. 1.0-Inch TIVICON Image Tube with Silicon Diode Array Shown Separately

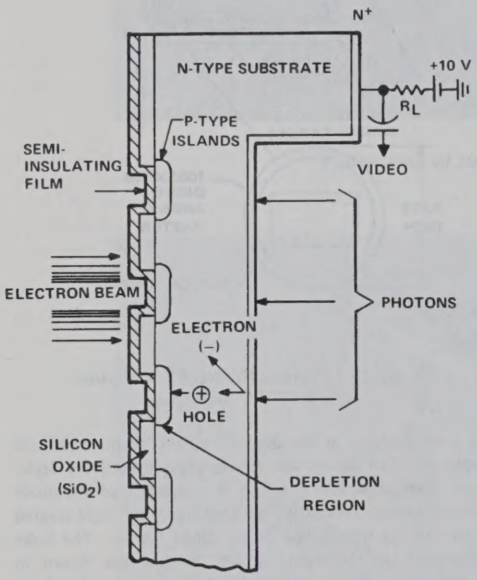

FIGURE 3. Cross Section of Silicon Diode Array

fabrication. Applying a semi-insulating film over the array will prevent the oxide from accumulating a charge; this charge-accumulation will hinder the electron beam's ability to interrogate the diodes and the electrons will, in fact, be repelled back toward the G_4 grid. The resistivity of the coating is chosen carefully to prevent a loss in resolution that may occur due to the shorting of adjacent diodes. In early tubes, metal islands were evaporated over the diodes to effectively remove the charge. The use of metal islands or other padded structures provided the advantage of a high temperature bake-out, but the disadvantage of a high defect count. The TIVICON image tube utilizes a "resistive sea" structure which is capable of high temperature bake out (250 to 400°C) but does not have the disadvantage of a high defect count.

PERFORMANCE OF THE TIVICON IMAGE TUBE

The following paragraphs are a summary of performance values obtained from manufacturing lots of TIVICON image tubes. Due to normal manufacturing variances, ranges of values are often shown. If further clarification of performance testing procedures are needed, reference should be made to the TIVICON Image Tube Test Methods explained in the Test Procedures section.

a. Sensitivity

The spectral sensitivity of a TIVICON image tube is determined by the type of material used as the light sensing layer (target). Using silicon in the TIVICON image tube has resulted in the broadest spectral response curves ever obtained in an image tube which possesses both visible and IR response. Also, using silicon with its high absorption coefficient has enabled the TIVICON to have the greatest quantum efficiencies ever obtained for an image tube. Figure 4 shows the spectral response of the TIVICON image tube. (The equivalent quantum efficiency curve is shown in Figure 5.) Also shown in Figure 4 are the spectral responses of the Plumbicon* and vidicon tubes as reported in published data sheets and papers.[3,4] The spectral response of the TIVICON image tube is from 0.35 microns to 1.2 microns – offering sensitivity to numerous types of light sources as shown in Figures 6 and 7.

The relation between tube output current and input irradiance (the light transfer characteristic) is often expressed logarithimically as:

$$\log I = \log k + \gamma \log w$$

where

I is output current from the light sensitive target in amps

γ is the power slope of the transfer characteristic of input irradiance w

w is the faceplate irradiance in watts/cm^2

k is the spectral sensitivity normalized for area

The TIVICON image tube γ is 1.0. The vidicon tube γ is 0.65, or higher, depending upon target voltage and light

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* Registered trademark of North American Philips Corp.

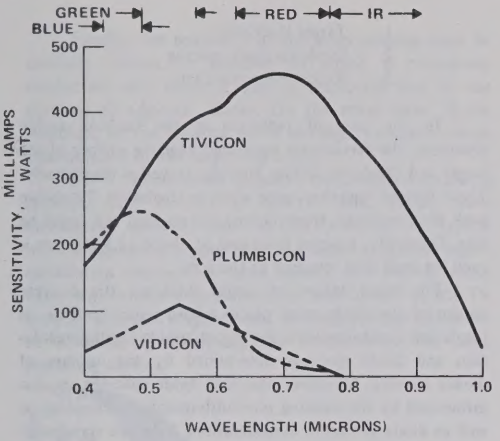


FIGURE 4. Spectral Responses of Two Different Types of TIVICON Image Tubes, a VIDICON Tube, and a Plumbicon® Tube

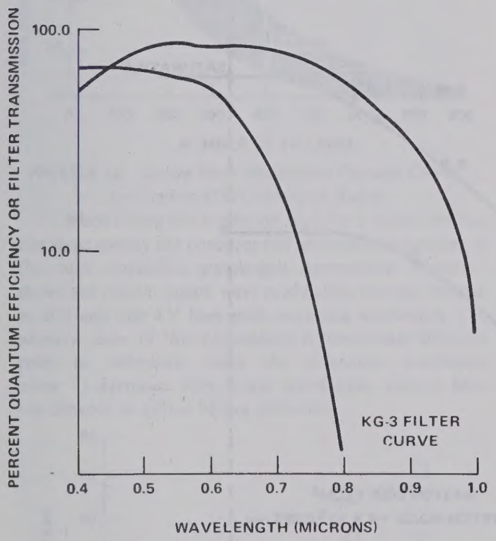


FIGURE 5. Quantum Efficiency of Two Different Types of TIVICON Image Tubes

level. Figure 8 shows a typical TIVICON image tube light transfer curve with a 3 X 10^{-9} amperes current being generated by 6 X 10^{-9} watts of peak optical power.

How these signal levels relate to what one might see using a high contrast resolution chart is shown in Figure 9.

In this illustration the limiting TV line resolution is plotted versus total signal level. The equivalent narrow band peak irradiance in microwatts per cm^2 and the equivalent unfiltered and filtered 2870°K illuminance levels are

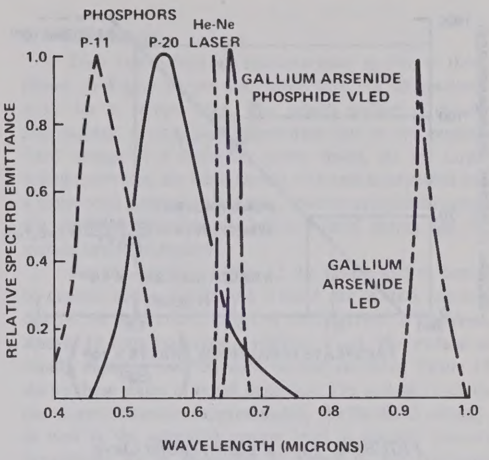


FIGURE 6. Sensitivity of TIVICON Image Tube to Phosphor and Narrow Band Light Sources

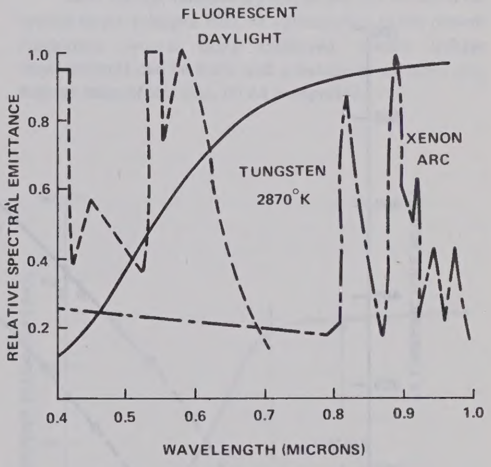


FIGURE 7. Sensitivity of TIVICON Image Tube to Typical Illumination Sources

indicated. The filtered scale was obtained by using a 5 millimeter thick Schott KG-3 visible pass filter. The transmission of this filter has been shown in Figure 5. The equivalent system peak signal to rms noise is also plotted The limiting noise parameter is the TV system preamplifier noise which was 9 X 10^{-9} amperes rms equivalent input current.

b. Resolution

The resolution of the silicon-diode array is limited by several factors. These include:

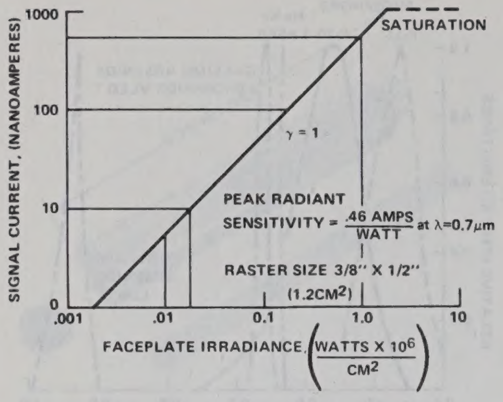


FIGURE 8. Typical Light Transfer Curve of TIVICON Image Tube

1. Target thickness
2. Diode-to-diode spacing
3. Resistive-sea resistivity

In the case of radiation in the far-blue visible spectrum, the carriers are generated near the surface of the target and the holes diffuse laterally as well as transversely. These factors, thereby, cause a loss in resolution. To obtain peak blue response, these factors dictate that the target be thin. Generally, a target thickness of about 12.5 microns is used for peak blue response of the array.

For some values of target thickness the discrete nature of the diode array places a hard upper limit on its resolution capability with the upper, usable limiting resolution and diode spacings determined by the number of diodes scanned. Moreover, the final diode spacings are also influenced by the existing photolithographic technology as well as diode geometry considerations from the standpoint of target capacitance (lag) and total array leakage.

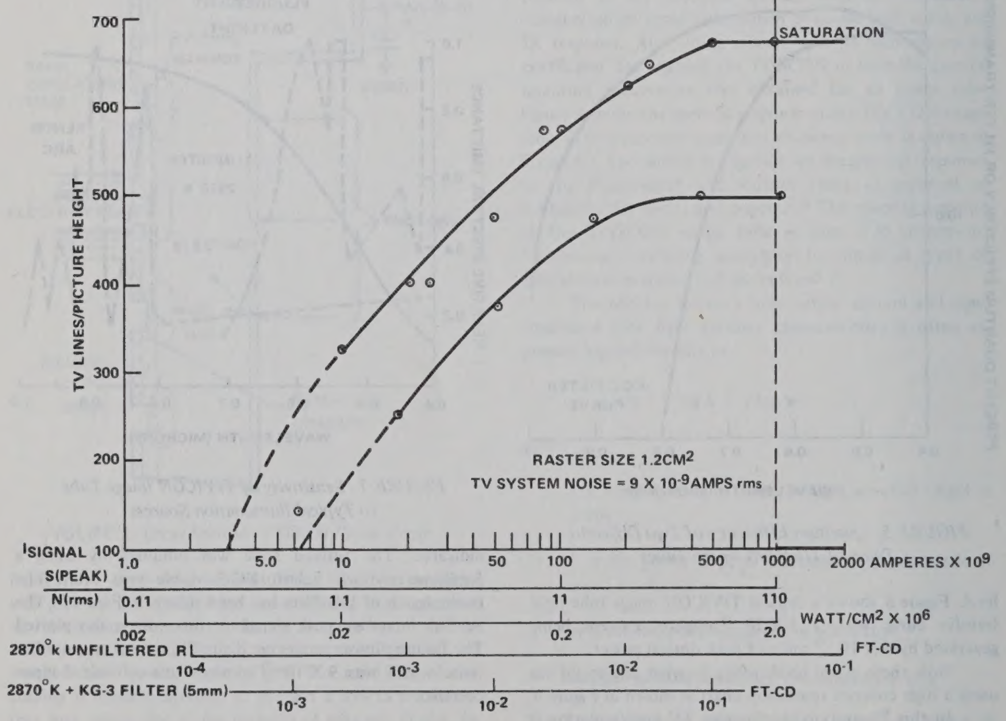


FIGURE 9. Limiting Resolution versus Signal Current of TIVICON Image Tube

Finally, the resistivity of the array coating must be carefully chosen. A resistive sea which is excessively conductive will cause a loss in resolution due to the shorting of adjacent diodes. On the other hand, if the resistance of the resistive sea is too high, excessive charge accumulation on the target will result.

For a 16-mm raster diagonal, the modulation value is typically 20% to 30% at 400 TV lines. Square wave modulation transfer function (MTF) curves for typical tubes are shown in Figure 10. It is possible to achieve higher modulation values than those shown, and indeed, many tubes will exhibit a modulation of 35% to 45% at 400 TV lines for a 16-mm diagonal scan. The higher modulation can be achieved by increasing the resistivity of the semi-insulating coating.

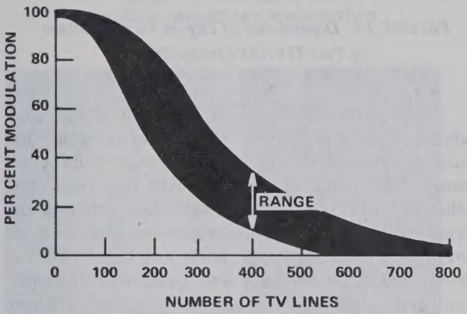


FIGURE 10. Square Wave Modulation Transfer Curves for Typical TIVICON Image Tubes

When taking the resolution data for a silicon vidicon one must specify the conditions of measurement because of the tube resolution wavelength dependence. Figure 11 shows the typical square wave modulation transfer increase at 300 and 400 TV lines with increasing wavelength. The primary cause of this dependence is lateral hole diffusion prior to collection. Since the absorption coefficient $\alpha(cm^{-1})$ decreases with longer wavelength, carriers have less distance to diffuse before collection.

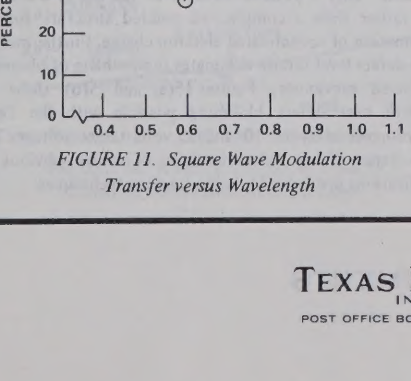


FIGURE 11. Square Wave Modulation Transfer versus Wavelength

c. Diode Leakage

Dark current-voltage characteristics similar to those shown in Figure 12 are obtainable with the silicon-diode array for a 16-mm scan. The silicon surface is intially accumulated at the Si-SiO$_2$ interface due to the positive fixed charge in a thermally grown oxide. As the target voltage increases, the dark current increases as expected and a more rapid increase in leakage is evident as the field across the oxide compensates the positive fixed charge and the surface begins to deplete.

For the target in Figure 12 the silicon surface begins to deplete above 5 volts and a rapid rise in dark current, due to the generation centers at the interface, is observed. Above 12 volts (saturation voltage, V_{sat}), the surface is totally depleted and the dark current saturates. Figure 13 shows these stages of target depletion. The voltage at which the current saturates (approximately the flat-band voltage), as well as the saturated current level, is strongly process dependent. As is explained in detail in the following section, it is desirable to operate the target in the saturated region from a low lag standpoint. It is possible to operate in this region without defect blooming effects.

Dark leakage values of 15 nA, or less, are obtained for typical target voltages. With an optimization of the present fabrication process being employed, further leakage improvements can be made and a maximum saturated dark leakage value of less than 10 nA is expected.

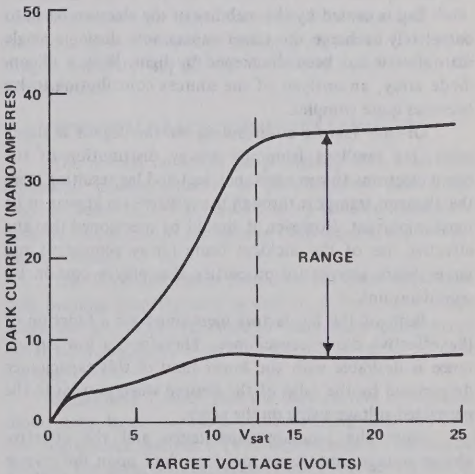


FIGURE 12. Dark Current/Voltage Characteristics of TIVICON Image Tube

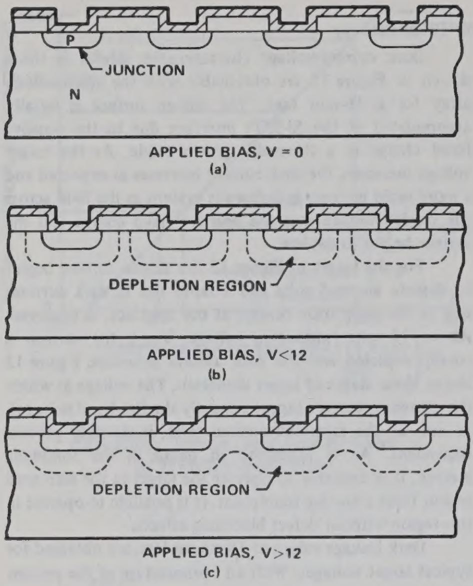


FIGURE 13. Stages Illustrating Depletion of Junction Region at Various Bias Voltages

d. Lag

Lag is caused by the inability of the electron beam to completely recharge the target capacitance during a single scan after it has been discharged by light. With a silicon-diode array, an analysis of the sources contributing to lag becomes quite complex.

Of the factors contributing to the lag of a diode array, lag resulting from the energy distribution of the beam electrons (beam resistance lag) and lag resulting from the electron transport through the resistive sea appear to be most important. However, it should be mentioned that the effective use of the incident beam (array geometry) and target beam acceptance properties also play a part in lag considerations.

Both of the lag factors mentioned are a function of the effective diode capacitance. Therefore, a low capacitance is desirable with the lower limit of this capacitance determined by the ratio of the desired video current to the permitted voltage swing on the array.

Since the junction capacitance and the effective charge storage capacitance are dependent upon the reverse bias voltage, lag is a strong function of target voltage. A plot of tube lag versus array voltage is shown in Figure 12 for two different TIVICON image tubes and 3rd and 4th field at 60 fields per second. Lag can be virtually eliminated with an increase of target voltage. The acceptability of reducing the lag in the manner shown in Figure 14 depends upon the ability to control defect blooming.

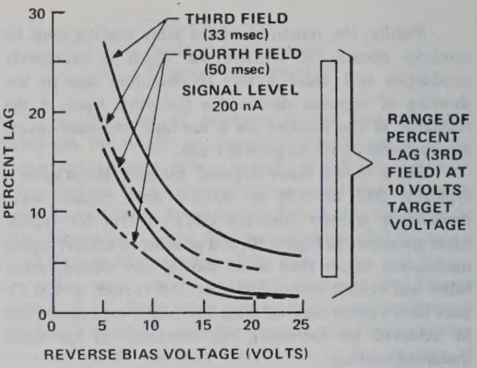
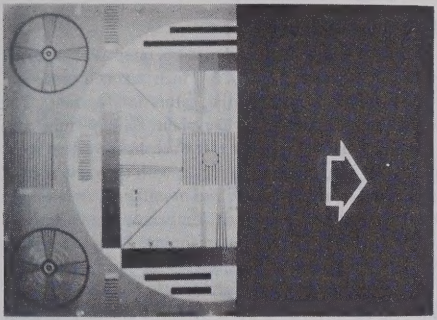


FIGURE 14. Dependence of Lag on Target Voltage of Two TIVICON Image Tubes

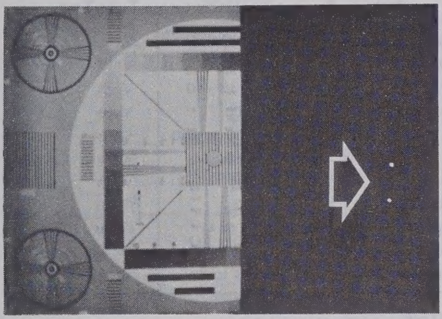
Several different methods of silicon diode array fabrication have been tried in an effort to reduce lag, increase resolution, and, in other ways, improve its performance. Usually the methods employed have resulted in either a resistive-sea or padded-structure configuration. Texas Instruments, early in its development of silicon diode arrays, used padded structures but it soon found that array defects and defect blooming were undesired by-products. Consequently, Texas Instruments developed a high-temperature resistive-sea structure which provides many advantages compared to padded structures. The methods used by various other companies usually employ a padded structure, and consequently, increasing voltage to reduce lag also causes increased defect counts and an enlargement (blooming) of the already visible defect. Such competitive arrays do not achieve the ultimate lag reduction obtainable with the Texas Instruments array.

e. Defects

The present Texas Instruments silicon-diode array processing techniques and clean-room facility yield targets with a low defect count. Typically on a 16-mm diagonal raster, there are no defects larger than 6 TV scan lines (525 scanline system) and there are fewer than 4 white and 4 black defects of 2 to 6 TV lines with no defects in the center 20%. Some TIVICON image tubes exhibit zero defects.* This is possible because of the use of a resistive sea rather than a complicated padded structure for the elimination of accumulated electron charge. Furthermore, a zero-defect level totally eliminates the problem of blooming discussed previously. Figures 15(a) and 15(b) show the control over defect blooming possible with the Texas Instruments array at 10 and 25 volts target voltage. The importance of low defect levels is, of course, obvious for applications involving TV video tracking techniques.



A
TARGET POTENTIAL 10 VOLTS
DARK CURRENT 14 NANOAMPERES



B
TARGET POTENTIAL 25 VOLTS
DARK CURRENT 15 NANOAMPERES

FIGURE 15. Resistance of TIVICON Image Tube to Defect Blooming

f. Blooming Properties And Optical Burn

Blooming in either vidicons, plumbicons, or silicon vidicons is due to the lateral spreading of light created minority carriers. A measure of the silicon vidicons blooming characteristics can be done by imaging a circular spot of light upon the light sensing layer and measuring the spot diameter change as a function of light intensity. Figure 16 is such a plot giving the ratio of final spot diameter D to the original diameter D_o as a function of relative light level. D_o was set at a value of 2.5 percent of the vertical picture height. There is only a slight increase in spot size over the normal tube operating range of one microampere but larger change is seen above tube saturation. A spot increase of four times the original D_o does not occur until a total light level change of 4000 to one for the worst case and in the best case 2.3 to one at 10,000 to one light level change. It is possible to minimize the blooming effects by a proper selection of array to cathode voltage V_{TK}. Figure 17 shows the relative spot diameter change D/D_o as a function V_{TK} for two different silicon vidicons. A demonstration of the ruggedness of the silicon vidicon to optical burn is shown by imaging a bright circular light spot on the silicon vidicon surface. The size of the spot was 26 percent of vertical picture height with an energy density of 100 microwatts/cm^2 or 100 times the typical saturation level of the tube. The tube was exposed to this level for 36 continuous hours. At the conclusion of this time period the tube was found to have the same sensitivity and dark current level at the spot as originally measured. The total integral exposure was 13 watt-seconds at a wavelength of 0.75 microns.

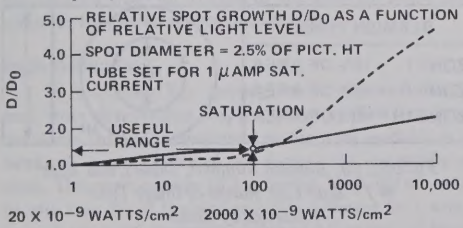


FIGURE 16. Relative Spot Growth due to Blooming versus Relative Light Level

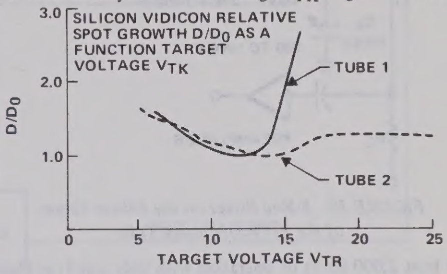


FIGURE 17. Blooming Dependence on T

TIVICON IMAGE TUBE RELIABILITY

The normal modes of image pick-up tube failure are accidental photoconductor or photoemitter light burn, electron beam raster burn due to sweep failures, thermionic cathode slump due to ion burn or other causes, and finally, vacuum leaks.

The TIVICON image tube does not demonstrate the light burning property seen in vidicon or Plumbicon image tubes and has more resistance to beam raster burn except raster burn caused by X-ray degradation of the target dark current.

It has been found[5] that the dark current of a silicon diode array target increases with operating time and that the degradation follows a $(V)^6$ dependence on mesh (G_4) voltage. The apparent mechanism is the X-ray generation by return electrons from the target. The X-rays change the silicon target properties toward higher I_{dark} values. Figure 18 shows the X-ray effect on the silicon target schematically.

An obvious fix on the degradation is to reduce the G_4 mesh potential, thus reducing the rate of degradation. Typically, 300 to 400 volts of G_4 voltage will give the user

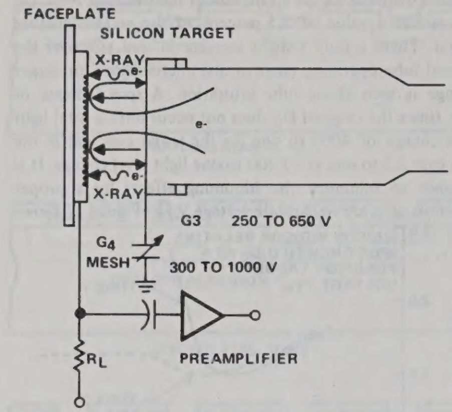


FIGURE 18. X-Ray Effect on the Silicon Target of the TIVICON Image Tube

at least 2,000 hours of operation with only a shift in black level depending upon the dynamic range of the TV system.

The remaining areas of failure, such as cathode slump, are expected to be greatly improved compared to regular vidicon tubes because of the high-temperature processing given the TIVICON image tube. The typical temperature range is 250°C to 350°C whereas a standard vidicon tube is currently processed at 125°C.

TEST PROCEDURES

Meaningful comparison of the TIVICON data sheets with those of other image tubes requires knowledge of the test techniques used. The TIVICON image tube procedure is described in this section. No specifications are included because of their variation with the tube type.

The Test System

The test system is operated with a 525-line, 30 frame-per-second, 2:1 interlaced scan standard. Channel bandwidth is flat ± 0.5 db to 12 MHz. Rms equivalent input current is 9 nanoamperes or less. All necessary voltages, currents and fields are supplied to the tube by the system.

The system gain is adjusted to produce 0.7 volts of video with 500 nA of highlight current. The pedestal is set at approximately 0.1 volts to prevent "crushing" of blacks. No special video processing is used during test, such as aperture correction, gamma correction, or white clipping. However, the video is clamped and the monitor dc restored.

The system layout is shown in Figure 19.

TIVICON Image Tube Set-Up

The TIVICON image tube is operated with a target potential of 10 volts, a 1/2 X 3/8 inch scanned area, and the beam set to discharge the saturation current. The horizontal scan is parallel to the plane through tube axis and the short index pin. For reference in recording spots the index pin is oriented to coincide with the right edge of the test chart *as displayed on the monitor*. A two-minute warmup is allowed for cathode temperature stabilization. The target requires no pre-test scanning. Scan-size adjustment and video setup is done with an 8 X 10-inch RETMA 1956 resolution chart transparency, back-illuminated by a variable color temperature incandescent source. Table 1 lists the typical setup potentials. The monitor contrast and brightness are set to display ten linear gray scale steps without blooming whites.

Table 1. Typical TIVICON Image Tube Test Operating Conditions

Cathode	0	Volts (reference)
G_1	0 to −40	Volts
G_2	300	Volts
G_3	450 to 550	Volts
G_4	650	Volts
Target	10	Volts
Focus Field	50	Gauss
Alignment Fields	0 to 4	Gauss
Scan Size	.375 x .5	Inches
Faceplate Temperature	25 to 30	°C

The Tests

The tests are of three types: target background, static performance, and dynamic performance. They may be made in any order without effect on the results.

Target Background

- Dark Current. With the target sealed off from light, the current which flows in the target lead is measured with an average-reading nanoammeter. (HP425A)
- Blemishes. White spots are counted with the target darkened and black spots are counted with uniform illumination on the target set to produce 200 nanoamperes of target current. The numbers, shades and sizes in TV scan line widths are recorded by zones (see Figure 20). Clusters are noted.

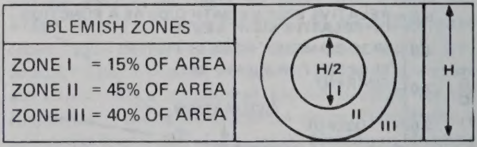


FIGURE 20. Blemish Numbers, Shades, and Sizes in TV Scan Line Widths of Image Tube Recorded by Zones

- Uniformity. The target is uniformly illuminated to produce a 200 nA signal. The oscilloscope is set to display

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* Spots of 1 TV line or less (single diode size) are generally not objectionable to the viewer. These are not counted as defects unless they are clustered or the concentration is high and causes a smudged appearance.

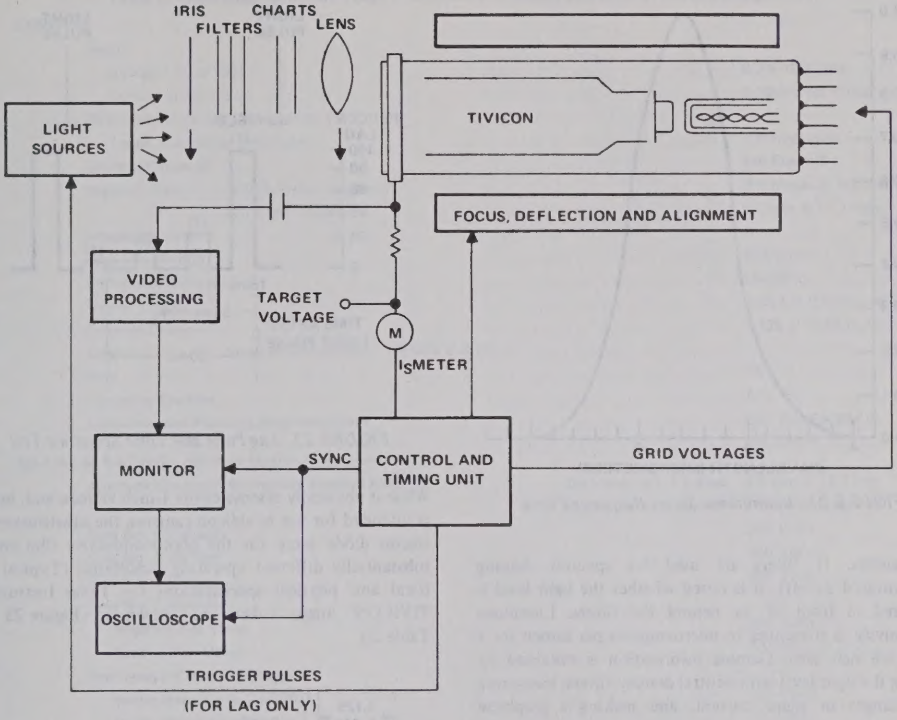


FIGURE 19. Block Diagram of TIVICON Image Tube Test System

one horizontal line halfway down the raster to be used as a reference. As the line selector is moved through the raster, deviations from the amplitude of a point in the center of the reference line are noted and expressed as a percentage of the difference between the illuminated and dark levels at that point. Both dark current and sensitivity variations and electron optics deficiencies are accounted for here.

- Distortion and Linearity. The camera is focused on a RETMA Linearity Chart ("ball chart") and its image is displayed on the monitor screen simultaneously with an electronically generated grating. With the center of the grating placed in the center ball the grating spacing and location is adjusted for best fit. Deviations of the grating intersections from the centers of the balls are noted and corrected for known system nonlinearities.

Static Performance

- Resolution. The limiting horizontal resolution is read from the monitor display using the RETMA 1956 resolution chart. The horizontal square-wave modulation is measured in the center of the raster using a multiburst chart. This chart consists of a reference black bar of width no less than 5% of the picture height followed by a white area of the same dimension followed by groups of black and white bars in spacings of 100 to 1000 TV lines per picture height. The amplitude of each burst is read from an oscilloscope display of a line in the center of the raster and expressed as a percent of the difference between the reference black and white levels. The curve must be corrected for known lens deficiencies. The charts must have contrast ratios of at least 100:1.

- Sensitivity. For spectral sensitivity, (radiant responsivity) a uniform monochromatic spot, approximately 20 percent of the picture height, is projected onto the target. The intensity is adjusted to give a signal in the 50- to 500-nanoampere range. The difference between the dark current and illuminated current is read from a properly calibrated oscilloscope display of a horizontal line through the spot. The intensity of the spot is measured and the sensitivity (amperes/watt) is calculated and corrected to a 1/2 X 3/8 inch area. From the sensitivity, the TIVICON tube's quantum efficiency may be calculated using the formula:

$$QE = 1.25 \times \frac{Sensitivity\ (Aw^{-1})}{Wavelength\ (\mu m)} \times 100\%$$

Luminous responsivity is measured in a similar fashion except that the source is a 2870°K unfiltered incandescent lamp. The light measuring device has a photopic response curve (Figure 21) which reads out in

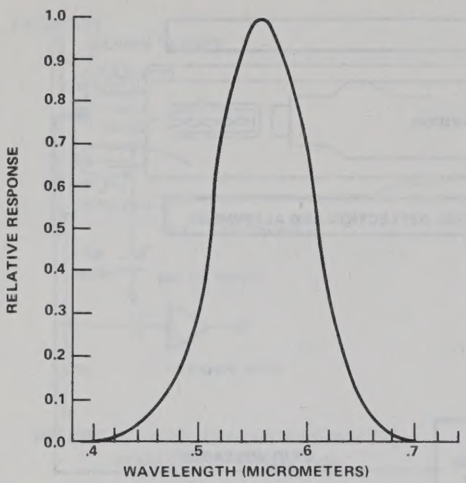


FIGURE 21. Illuminance Meter Response Curve

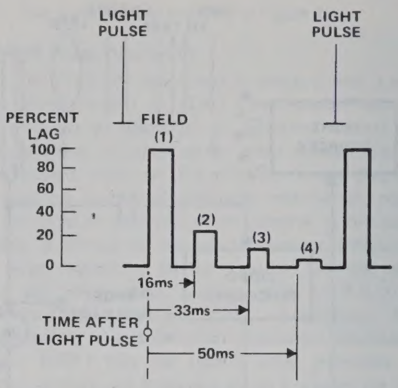


FIGURE 22. Lag Pulse and Time Sequence Test

foot-candles. If filters are used for spectral shaping (e.g., infrared cutoff), it is noted whether the light level is measured in front of, or behind the filters. Luminous responsivity is presented in microamperes per lumen for a 1/2 X 3/8 inch area. Gamma information is obtained by varying the light level with neutral density filters, measuring the changes in signal current, and making a graphical calculation.

- Blooming. A uniform spot of light, approximately 1% of the picture height, is projected on the target. The apparent diameter of the spot is recorded as its intensity is increased to a level 1000 times the intensity required for saturation.

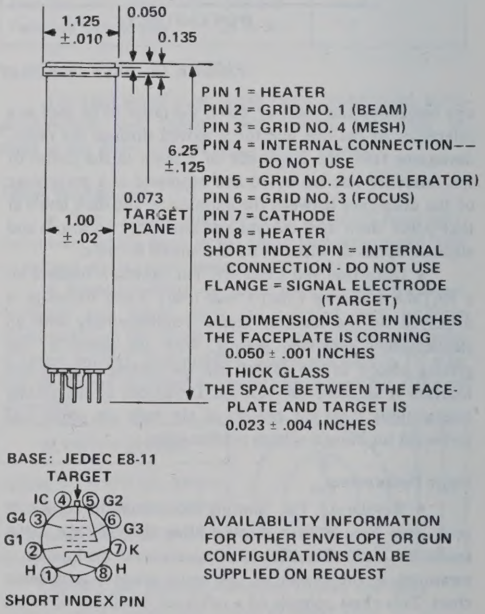
Dynamic Performance

- Lag. The camera is focused on a small, translucent white disc, back-illuminated by a strobe which fires during vertical retrace every fourth field. The video pulse generated in the center of the raster is displayed on an oscilloscope. The height of the first field pulse is set to some predetermined current level, typically 200 nanoamperes, and the height of the third field pulse is read out as illustrated in Figure 22. The lag is the ratio of the third field pulse height to the pulse height of the first field, expressed in percent. Complete decay curves are determined by lengthening the time between strobe flashes. The pulse height is plotted as a function of field.

Other tests can also be made but most are too specialized to be included here. Information on these can be obtained from Texas Instruments.

OPERATING THE TIVICON IMAGE TUBE

The Texas Instruments TIVICON image tube is different from any other image tube you have ever used. While it physically resembles the 1-inch vidicon and, in fact, is intended for use in vidicon cameras, the substitution of a silicon diode array for the photoconductive film gives it substantially different operating conditions. (Typical electrical and physical specifications for Texas Instruments TIVICON image tubes are shown in Figure 23 and Table 2.)



PIN 1 = HEATER
PIN 2 = GRID NO. 1 (BEAM)
PIN 3 = GRID NO. 4 (MESH)
PIN 4 = INTERNAL CONNECTION—DO NOT USE
PIN 5 = GRID NO. 2 (ACCELERATOR)
PIN 6 = GRID NO. 3 (FOCUS)
PIN 7 = CATHODE
PIN 8 = HEATER
SHORT INDEX PIN = INTERNAL CONNECTION - DO NOT USE
FLANGE = SIGNAL ELECTRODE (TARGET)
ALL DIMENSIONS ARE IN INCHES
THE FACEPLATE IS CORNING 0.050 ± .001 INCHES THICK GLASS
THE SPACE BETWEEN THE FACEPLATE AND TARGET IS 0.023 ± .004 INCHES

AVAILABILITY INFORMATION FOR OTHER ENVELOPE OR GUN CONFIGURATIONS CAN BE SUPPLIED ON REQUEST

FIGURE 23. Outline Drawing of Texas Instruments TIVICON Image Tube

Table 2. Data Description of Texas Instruments One-Inch (25 mm) TIVICON Image Tube

GENERAL		
Heater:		
Voltage (AC or DC)		6.3 ± 10% Volts
Current at 6.3 Volts		0.300 Amps ± 10%
Direct Interelectrode Capacitance		
Target to all other Electrodes		4.0 Picofarads
Spectral Response		See Figure 4
Scanned Area	(0.625 Inches Diagonal)	3/8 Inches X 1/2 Inches
	(15.9 mm Diagonal)	9.5 mm X 12.7 mm
Image Orientation		Any
Focusing Method		Magnetic
Deflection Method		Magnetic
Overall Length		6.25 ± 0.125 Inches
Greatest Diameter		1.125 ± 0.010 Inches
Base	Small Button Ditetrar (JEDEC E-8-11)	
Bulb		T8
Operating Position		Any
Deflection and Focusing Alignment Coils		CEI VYLFA 857 or Equivalent
MAXIMUM RATINGS Absolute Maximum Values[a,b]		
Absolute Maximum Ratings for Scanned Area	3/8 Inches X 1/2 Inches (0.625 Inches Diagonal)	9.5 mm X 12.7 mm (15.9 mm Diagonal)
Grid No. 4 Voltage[c]		350 Volts
Grid No. 3 Voltage[c]		350 Volts
Grid No. 2 Voltage		350 Volts
Grid No. 1 Voltage		
Negative Bias Value		150 Volts
Positive Bias Value		0 Volts
Peak Heater-Cathode Voltage		
Heater Negative to Cathode		125 Volts
Heater Positive to Cathode		10 Volts
Target Voltage		10 Volts
Faceplate		
Illumination		10^7 Foot-Candles
Temperature — Operating		55°C
— Storage		100°C
TYPICAL OPERATING CONDITIONS FOR LONG LIFE [Scanned Area of 3/8 Inches (9.5 mm X 12.7 mm)] [b]		
Target Voltage		10 Volts
Grid No. 4 Voltage[c]		350
Grid No. 3 Voltage[c]		280
Grid No. 2 Voltage		300
Grid No. 1 Voltage for Picutre Cutoff		−40 to −75 Volts
Peak-to-Peak Blanking Voltage		
When Applied to Grid No. 1		30 Volts
When Applied to Cathode		10 Volts
Target Highlight Current[d]		500 Nanoamperes
Field Strength at Center of Focus Coil		42 ± 5 Gauss
Field Strength of Adjustable Alignment Coil		0 to 4 Gauss
OPERATING CONDITIONS FOR HIGH RESOLUTION (As above except:)		
Grid No. 4 Voltage		650 Volts
Grid No. 3 Voltage		520 Volts
Grid No. 2 Voltage		300 Volts
Focus Field		56 Gauss

a) The maximum ratings in the tabulated data are established in accordance with the following definition of the Absolute Rating system for rating Electron Devices: Absolute Maximum Ratings are limiting values of operating and environmental conditions applicable to any Electron Device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

b) At 20°C all voltages (except header voltage) are given with respect to cathode.

c) Grid No. 4 Voltage must be equal to or greater than Grid No. 3 Voltage. The recommended ratio of Grid No. 3 to Grid No. 4 Voltage is 8/10 to 9/10.

d) The video amplifier must be able to handle this target current to avoid amplifier overload or picture distortion.

Camera Modification Necessary to Use TIVICON Image Tube

Some cameras will not operate the TIVICON image tube properly without modification. The most common modification involves disabling the automatic light control (ALC) of the type which raises the target voltage to compensate for decreasing light input. Since the sensitivity of the TIVICON image tube is unaffected by changes in target voltage, the effect of ALC is to raise the target voltage to the point where the target begins secondary emission of electrons. This manifests itself as a blackening of the image, usually in the corners at first. The effect may be eliminated by lowering the target voltage. Secondary emission does not destroy the tube, even if sustained for long period. But to eliminate secondary emissions, the ALC should be disabled and the target adjust pot connected to a supply voltage which will allow reasonably fine adjustment in the 0 to 20 volt range. On many cameras there is a switch, either inside or outside the camera, which allows changing from ALC to manual operation.

In common-mesh cameras there are two approaches to operating the TIVICON image tube: 1) convert the tube to common-mesh operation, or 2) convert the camera to separate-mesh operation. To convert the camera to separate-mesh operation, merely connect pin 3 of the tube socket to the same voltage which is supplied to the focus pot. To convert the tube to common-mesh operation, strap pins 3 and 6 together. If operated in this manner some degradation in distortion and resolution may occur.

In cameras with current-regulated filament supplies an adjustment may be necessary to prevent overdriving the TIVICON image tube heater. Operation of the filament outside the recommended range may severely shorten its life. Cameras with voltage-regulated supplies or filament transformers require no changes.

RUGGEDIZED TIVICON IMAGE TUBES FOR MILITARY USE

Texas Instruments has been developing and manufacturing ruggedized silicon vidicon image tubes for several years. In addition to demonstrating survivability in actual military flight tests, the ruggedized TIVICON image tube has also shown low microphonic levels at 10 g vibration levels.

The ruggedized TIVICON image tube employs a strong electron gun that has been designed for minimum motion. It also uses a unique technique for target mounting eliminating target to mesh motion, one of the major causes of microphonics. This method of target mounting also maintains a flat target surface which is parallel to the faceplate and not subject to the target crinkling which is a major disadvantage of spring-mounted targets.

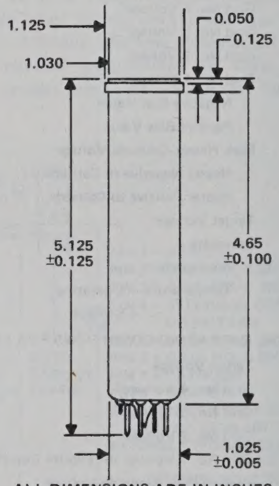
Table 3 summarizes the various military specification tests to which the ruggedized TIVICON image tube has been subjected. A cross section diagram of this tube is shown in Figure 24.

Table 3. Environmental Specifications

A. Mechanical
  1. Altitude – Sea level to 30,000 ft.
  2. Vibration
    a. Sinusoidal – MIL-STD-810B, Test Method 514, Procedure/Curve D 10G's
    Test Method 516, Procedure (15G's)
    Sinusoidal – MIL-STD-E5400 Figure 2, Curve 1 20-500CPS, 10G's
    b. Random – 7.0-g RMS for 20 minutes (no failure)

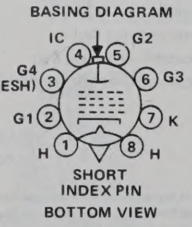
B. Temperature
  1. Operating – The maximum gray shade degradation shall not exceed 2 shades (linear) in the temperature range of –10.0°F to 125°F when operated in a TV system capable of accepting 1000 nanoamps of input video current without saturation.
  2. Non-operating – –54°C to 100°C (200°C on request)

OUTLINE DIMENSIONS



ALL DIMENSIONS ARE IN INCHES

TERMINAL CONNECTIONS



PIN 1: HEATER
PIN 2: GRID NO. 1 (BEAM)
PIN 3: GRID NO. 4 (MESH)
PIN 4: INTERNAL CONNECTION DO NOT USE
PIN 5: GRID NO. 2 (ACCELERATOR)
PIN 6: GRID NO. 3 (FOCUS)
PIN 7: CATHODE
PIN 8: HEATER
FLANGE: SIGNAL ELECTRODE (TARGET)
SHORT INDEX PIN: INTERNAL CONNECTION DO NOT USE

FIGURE 24. Outline Drawing of Ruggedized TIVICON Image Tube for Military Use

TWO-THIRDS INCH (18 mm) TIVICON IMAGE TUBE

The silicon target and electron gun structure of the two-thirds inch TIVICON image tube function the same as those structures in the one-inch TIVICON image tube. Primary performance differences between the two tubes occur because the scanned raster is 0.58 cm^2 in the two thirds inch tube and 1.2 cm^2 in the one inch tube. Because of the smaller scanned area the performance figures, such as dark current and resolution, are lower in absolute value in the smaller diameter tube. Conversely, parameters such as image retention and degradation are better because of the higher beam current density in the raster area and the lower standard voltage on the G^4 grid.

Sensitivity and Spectral Response

Because the two-thirds inch TIVICON image tube employs the same type silicon target as the one-inch TIVICON tube, its spectral sensitivity curve is identical to the spectral sensitivity curve for the one inch tube as shown in Figure 4. The peak response is 450 milloamps per watt and peaks at 0.7 microns wavelength. The effect of the smaller raster area is shown in the transfer curve shown in Figure 25.

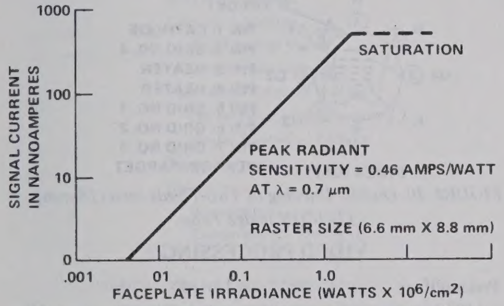


FIGURE 25. Transfer Curve of Two-Thirds Inch TIVICON Image Tube

A comparison of the sensitivity of the two-thirds inch TIVICON tube with the sensitivity of a two-thirds inch vidicon clearly shows the improved system performance of the TIVICON image tube.

Resolution

The resolution of any scanning beam image tube is directly proportional to the raster diagonal. Consequently, the range of modulations obtained at any given line rate is less as shown in Figure 26 for the 18 mm TIVICON tube when scanning a standard 8.8 mm X 6.6 mm (11 mm diagonal) raster. The limiting resolutions occurring at the 3 percent modulation point range from 350 to 500 TV lines per picture height.

Diode Leakage

The average dark current measured is the sum of all the scanned diodes and hence, it is a function of the raster area. Figure 27 shows the dark current versus target voltage.

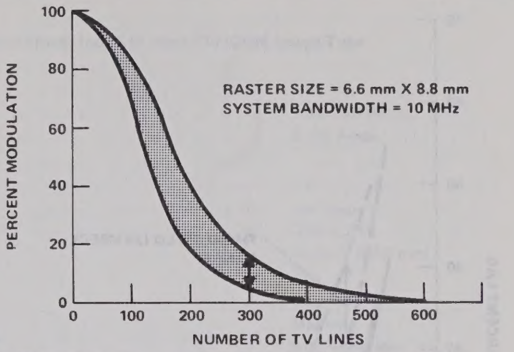


FIGURE 26. Square Wave Modulation Transfer Curves for Typical Two-Thirds Inch TIVICON Image Tube

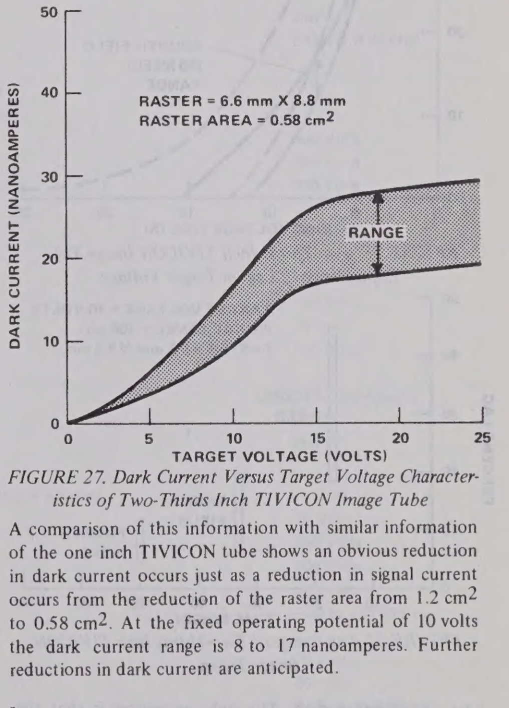


FIGURE 27. Dark Current Versus Target Voltage Characteristics of Two-Thirds Inch TIVICON Image Tube

A comparison of this information with similar information of the one inch TIVICON tube shows an obvious reduction in dark current occurs just as a reduction in signal current occurs from the reduction of the raster area from 1.2 cm^2 to 0.58 cm^2. At the fixed operating potential of 10 volts the dark current range is 8 to 17 nanoamperes. Further reductions in dark current are anticipated.

Lag

Data plots representative of the 18 mm TIVICON tube are shown in Figures 28 and 29. Figure 28 shows the lag-target voltage dependence curves. Figure 29 shows the time delay curve of the tube showing the second, third and fourth fields. These fields correspond to 17, 33 and 50 milliseconds after light extinction respectively.

Summary of the Advantages of the Two-Thirds Inch TIVICON Image Tube

The two-thirds inch TIVICON image tube provides all of the advantages available with the one-inch TIVICON

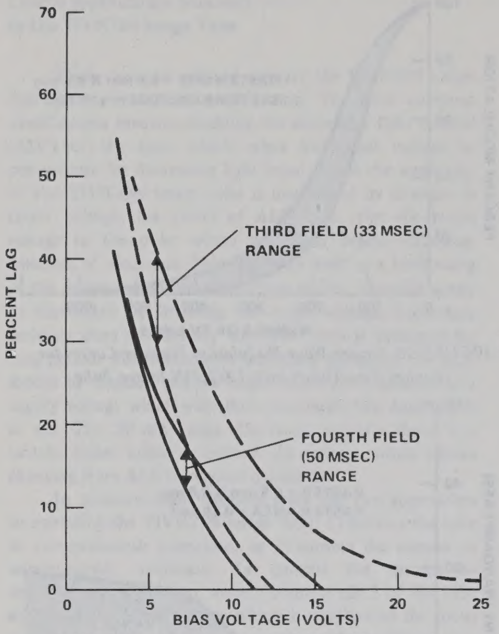


FIGURE 28. Two-Thirds Inch TIVICON Image Tube Dependence of Lag on Target Voltage

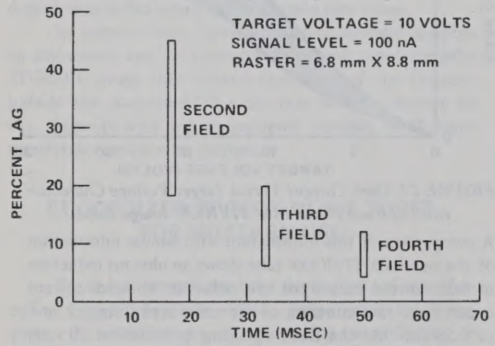


FIGURE 29. Lag Range of Two-Thirds Inch TIVICON Image Tubes

tube in a smaller tube. The only exception is that the resolution of the smaller tube compared to the larger TIVICON tube would not be as good.

The extremely high sensitivity and low lag of the two-thirds inch TIVICON image tube makes using it in present two-thirds inch vidicon systems a necessity. Also the high infrared sensitivity of the tube provides the traditional improvements experienced in the one-inch TIVICON camera applications such as industrial security.

Table 4 summarizes the Texas Instruments two-thirds inch TIVICON image tube data. Figure 30 is a dimensional drawing of this tube.

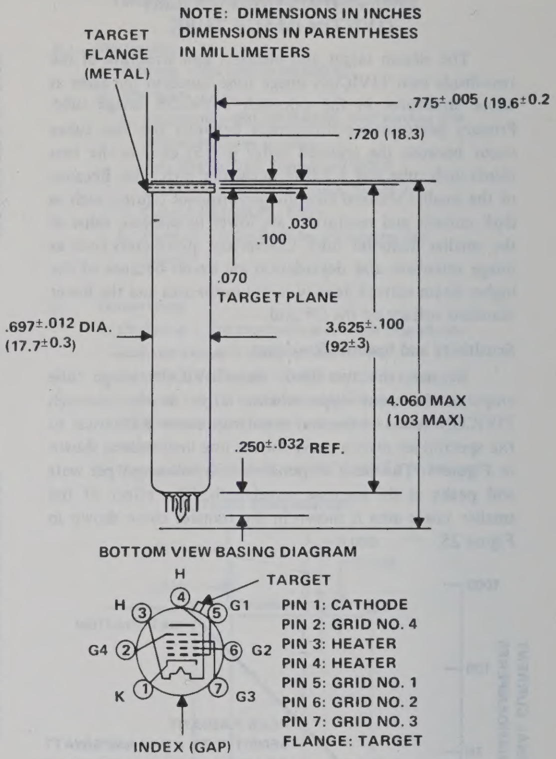

NOTE: DIMENSIONS IN INCHES
DIMENSIONS IN PARENTHESES IN MILLIMETERS
TARGET FLANGE (METAL)
.775±.005 (19.6±0.2
.720 (18.3)
.030
.100
.070
TARGET PLANE
.697±.012 DIA. (17.7±0.3)
3.625±.100 (92±3)
4.060 MAX (103 MAX)
.250±.032 REF.
BOTTOM VIEW BASING DIAGRAM
H
TARGET
H
G1
G4
G2
K
G3
INDEX (GAP)
PIN 1: CATHODE
PIN 2: GRID NO. 4
PIN 3: HEATER
PIN 4: HEATER
PIN 5: GRID NO. 1
PIN 6: GRID NO. 2
PIN 7: GRID NO. 3
FLANGE: TARGET

FIGURE 30. Outline Drawing of Two-Thirds Inch (18 mm) TIVICON Image Tube

VIDEO PROCESSING

Preamplifiers

Most vidicon preamplifiers can handle the increased signal of the TIVICON image tube, however, some inexpensive preamps have been known to overload, causing clipping. The most serious detriment to good performance of the TIVICON image tube is the extremely high target supply resistors used in some cameras. These large resistors can adversely affect the recharge cycle causing high lag. They also lead to excessive changes in target voltage under high signal conditions. If possible, the target resistor should be no larger than a few megohms. Since the target-to-gun capacitance of the TIVICON image tube is about the same as that of a vidicon, the frequency response of the preamp will not be affected by the tube change.

Processors

Processing of the TIVICON image tube video signal is handled the same as with vidicon tube signals. For a given light level and lens setting, less gain will be required with the TIVICON image tube because of its increased sensitivity. Because the TIVICON image tube is a constant sensitivity device, AGC is recommended to increase the

Table 4. Data Description of Texas Instruments Two-Thirds Inch (18 mm) TIVICON Image Tube

GENERAL	
Heater for Unipotential Cathode	
Voltage (AC or DC)	6.3 ± 10% Volts
Current at 6.3 Volts	0.095 Amps
Direct Interelectrode Capacitance	
Target to all Other Electrodes	3 pf
Spectral Response	See Figure 4
Scanned Area (0.435 Diagonal) (11 mm)	.260 X .346 (6.6 mm X 8.8 mm)
Image Orientation	Any
Focusing Method	Magnetic
Deflection Method	Magnetic
Overall Length	4.00 Inches Max
Greatest Diameter	0.775 Inches ± 0.005 Inches
Base	Small Button Ditetrar
Operating Position	Any
Deflection and Focusing Alignment Coil	SANYO R-W-1861
MAXIMUM RATINGS, Absolute Maximum Values[a,b]	
For Scanned Area of 0.260 X 0.346 (0.435 Diagonal) (6.6 X 8.8 mm) (11 mm Diagonal)	
Grid No. 4 Voltage[c]	400 Volts
Grid No. 3 Voltage[c]	350 Volts
Grid No. 2 Voltage	350 Volts
Grid No. 1 Voltage	
Negative Bias Value	150 Volts
Positive Bias Value	0 Volt
Peak Heater-Cathode Voltage:	
Heater Negative to Cathode	125 Volts
Heater Positive to Cathode	10 Volts
Target Voltage	100 Volts
Faceplate:	
Illumination	10^{+7} Foot-Candles
Temperature – Operating	55°C
– Storage	200°C
TYPICAL OPERATING CONDITIONS[b]	
For a Scanned Area of 0.260 Inches X 0.346 Inches (6.6 X 8.8 mm)	
Target Voltage	10 Volts
Grid No. 4 Voltage[c]	350 Volts
Grid No. 3 Voltage[c]	300 Volts
Grid No. 2 Voltage	300 Volts
Grid No. 1 Voltage for Picture Cutoff	−30 to −75 Volts
Peak-to-Peak Blanking Voltage	
When Applied to Grid No. 1	75 Volts
When Applied to Cathode	35 Volts
Target Highlight Current[d]	0.25 μA to 0.50 μA
Field Strength at Center of Focus Coil	55 ± 5 Gauss
Field Strength of Adjustable Alignment Coil	0 to 4 Gauss

a) The maximum ratings in the tabulated data are established in accordance with the following definition of the Absolute Rating system for rating Electron Devices: Absolute Maximum Ratings are limiting values of operating and environmental conditions applicable to any Electron Device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

b) At 20°C all voltages (except header voltage) are given with respect to cathode.

c) Grid No. 4 Voltage must be equal to or greater than Grid No. 3 Voltage. The recommended ratio of Grid No. 3 to Grid No. 4 Voltage is 8/10 to 9/10.

d) The video amplifier must be able to handle this target current to avoid amplifier overload or picture distortion.

dynamic range of the TIVICON-image tube camera combination. For scenes with predominantly low luminance but very bright highlights (for example, a parking lot at night with mercury arc lamps) white peak clipping is recommended to prevent streaking due to amplifier overload. A hard clamp is also helpful in this situation. For accurate rendition of gray scale, gamma correction is recommended. Since the TIVICON image tube is linear, a correction of about 0.5 should closely compensate for the larger-than-unity gamma of the CRT phosphor.

Light, Lenses and Filters

The TIVICON image tube works well with most light sources, but only those sources containing infrared can fully utilize the TIVICON image tube's wide spectral bandwidth. Incandescent lights, in particular, allow the TIVICON image tube to "see" in light levels which appear quite low to the eye. Xenon-arc lights also are a good spectral match. Mercury-arc lamps and fluorescent lights are not matched as well due to their low near-infrared content. Figures 6(a) and 6(b) show the spectral emittance of some typical light sources. For operation in the dark, either filtered incandescent, or xenon lamps, or gallium arsenide light-emitting diodes may be used to provide infrared-only illumination. Exotic sources such as the neodymium-glass lasers radiating at 1.06 μm also fall within the useful bandwidth of the TIVICON image tube.

Proper gray scale rendition can be accomplished only if the infrared is filtered out of the light falling on the TIVICON image tube faceplate. Such effects as whitening of foliage will occur if this is not done. Where sensitivity is more important than gray scale renditions, the infrared should be retained.

Most lenses work extremely well with the TIVICON image tube. The most noticeable difference between a vidicon and TIVICON image tube is a slight shift in focus if the source is changed from visible to infrared. Inexpensive lenses may not be able to present a crisp image at their larger f-stops when wideband sources of illumination are used. Internal lens reflections have about the same effect with the TIVICON image tube as they do with a vidicon, although an apparent increase in reflection intensity may occur in lenses which have poor anti-reflectance coatings. This is a consequence of the infrared sensitivity of the TIVICON image tube.

Because of the small space between the target and faceplate, the mechanical focus point will be shifted slightly. Nearly all cameras can compensate for this shift either by shifting of the lens mount or the coil assembly.

Although the TIVICON image tube cannot be damaged by high light levels, it may be necessary to equip the camera with an automatic-iris lens, or some form of neutral-density wedge, for use where scenes with changing light levels are to be observed. Texas Instruments has studied such techniques for increasing the dynamic range of the device and can make recommendations for many typical situations.

The wide spectral bandwidth of the TIVICON image tube allows a new latitude in spectral shaping. The TIVICON image tube may be used in a visible-only mode (filter: Schott KG-3) or an infrared-only mode (Corning 7-56). It may be used with any of the common color TV separation filters in conjunction with an infrared cutoff filter. In such cases the TIVICON image tube has an advantage of more than 7 to 1 over lead-oxide tubes in the red channel. The TIVICON image tube is better by a 1.2 factor in blue and green. It may be used with a narrow-band interference filter for making real-time thermograms above 200°C. In addition, special tailoring of the target can be done to increase efficiency in the 0.95 to 1.1 μm range for laser applications. Filters can also be used to increase the contrast ratio in inherently low-contrast scenes. Texas Instruments has experimented with filtration and can recommend proper filtering for your applications.

Setup

Once it has been determined that the TIVICON image tube will operate in the camera, the tube should be inserted into the coil and the socket connected. The beam control should be turned down and the target control set on minimum. The lens should be inserted and the camera covered to keep stray light off of the faceplate. Due to the high sensitivity of the tube, it is possible to wash-out the picture with very little stray light. Now the camera may be turned on.

The beam should be set about two-thirds "on". The lens should be adjusted for f/4 in normal room light. The target voltage should be raised until discharge is noted on the picture. This will happen somewhere below 10 volts. The camera should then be focused both electronically and mechanically. The mechanical focus point will be slightly different from the normal vidicon setting due to the space between the faceplate and the target.

The camera controls should be adjusted for best picture, keeping in mind the limits as quoted on the Description Sheet. The manual for the camera should be reviewed for adjustments such as mesh voltage, alignment, focus field and scan size. Picture parameters which should be considered are spots (both size and number), lag, saturated tails, uniformity, and apparent contrast – a function of dark current. The following chart will serve as a guide for achieving optimum performance from the TIVICON image tube.

Spots–	Normally will not change unless the target voltage is excessively high.
Lag–	Will decrease with increasing target voltage, and is a minimum for a given target voltage when the beam is set to just discharge the highlights.
Tails–	Occur only when the target voltage is too high or when the beam is very low. If the target voltage is set excessively high the bright areas may turn black. To cure this, cover the lens and lower the target voltage.

Uniformity– Uniformity will generally get better with higher target voltage, at least to the point where dark current variations begin to show. A mesh voltage which is either too high or too low can adversely affect the uniformity.

Contrast– The sensitivity of the tube is not a function of target voltage. Increasing this voltage will allow higher peak signal currents, but this will also increase the dark current, causing loss of contrast in dim scenes. The recommended voltage quoted is a good guide for maximum dynamic range.

REFERENCES

1. M. H. Crowell, T. M. Buck, E. F. LaBuda, J. V. Dalton, and E. J. Walsh, "A Camera Tube with a Silicon Diode Array Target," *BSTJ*, 46, No. 2 (February 1967), 491-495.
2. T. M. Buck, H. C. Casey, Jr., J. V. Dalton, and M. Yamin, "Influence of Bulk and Surface Properties on Image Sensing Silicon Diode Arrays," *BSTJ*, 47, No. 9 (November 1968), 1827-1854.
3. R. S. Levitte, "The Performance and Capabilities of Recently Developed Plumbicon* TV Camera Pick-Up Tubes," 105th Technical Conference SMPTE April, 1969.
4. RCA-8507 R Data Sheet 10-63.
5. G. E. Smith, "The Silicon Diode Array Camera Tube," Bell Telephone Laboratories Proceedings of the 1970 Solid State Circuit Conference.

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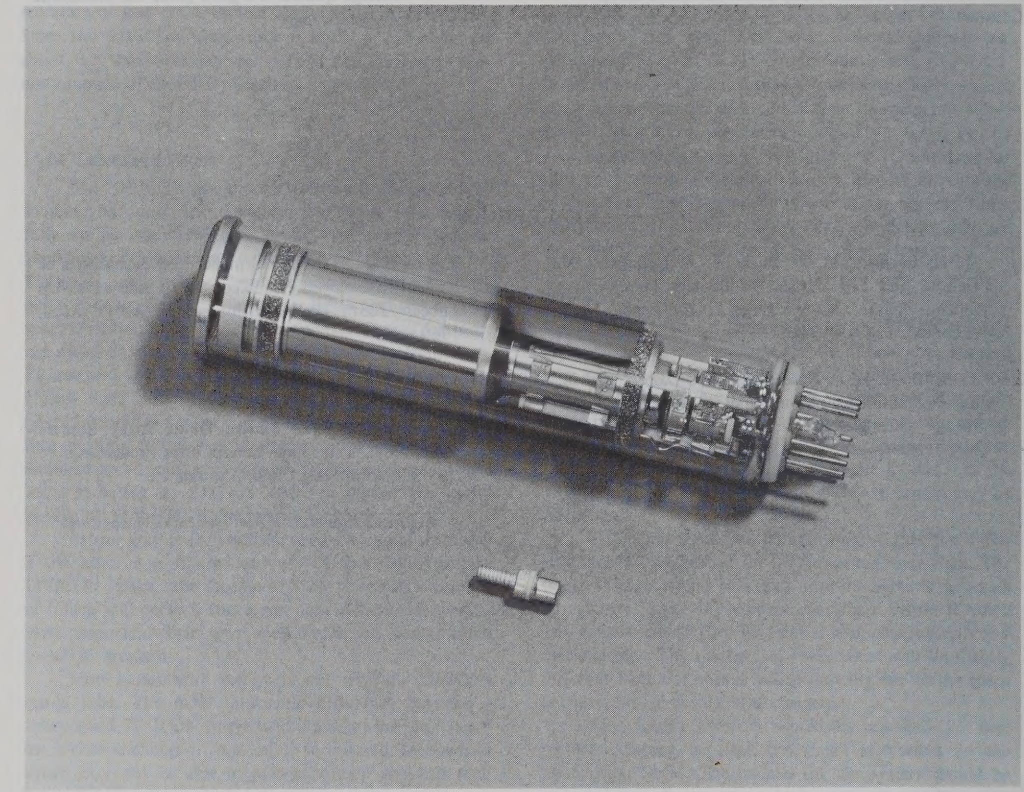
* Registered trademark of North American Philips Corp.



10

Thermal Printers

11

QUICK REFERENCE GUIDE
THERMAL PRINTERS

THERMAL PRINTERS QUICK REFERENCE GUIDE

DEVICE	ARRAY TYPE (COLUMN X ROW)	CHARACTER CAPABILITY	PRINT MODE	MAXIMUM SPEED	NUMBER OF DRIVERS REQUIRED	CHARACTER SIZE (WIDTH X HEIGHT)	AVERAGE POWER/ PULSE (WATTS)	FEATURES
EPN2100	4 X 5	Numeric	Row Strobed	9 Characters/ Second	None	0.064" X 0.100"	1.4	Gives permanent dry printing on hard-copy thermal paper. Includes decode/ driver circuitry on printer chip.
EPN2200	5 X 7	ASC11 and Lower Case	Simultaneous	30 Characters/ Second	5	0.080" X 0.100"	6	Offers complete alphanumeric print capability. EPN2201 includes decode/ driver circuitry in separate dual-in-line packages.
EPN2300	4 X 5	Numeric-Dot	Row Strobed	10 Characters/ Second	2	0.064" X 0.100"	1.4	EPN2301 has decode/ driver in separate dual-in-line packages. No stand-by power required.
EPN2400[†]	25 X 1 (5 each/ character)	ASC11 and Lower Case	Simultaneous	300 Char. Lines/ Minute	4	0.070" X 0.100"	8.4	Offers complete alphanumeric on a line-by-line basis for high-speed printout.
EPN2500[†]	5 X 5	ASC11	Row Strobed	12 Characters/ Second	2	0.084" X 0.100"	1.7	Gives alpha-numeric readout on thermographic paper. Low power consumption. No stand-by power required.
EPN2600[†]	5 X 5	ASC11	Simultaneous	30 Characters/ Second	5	0.084" X 0.100"	6	Offers alpha-numeric print capability on hard-copy thermographic paper.
EPN2700[†]	7-segment (4 digits/ package)	Numeric	Segment Strobed	300 Lines/Minute	3	0.084" X 0.100"		High-speed numeric print capability. Includes function indicator in separate package.

[†] These products are presently under development and will be released as standard products with defining specifications at a later date.

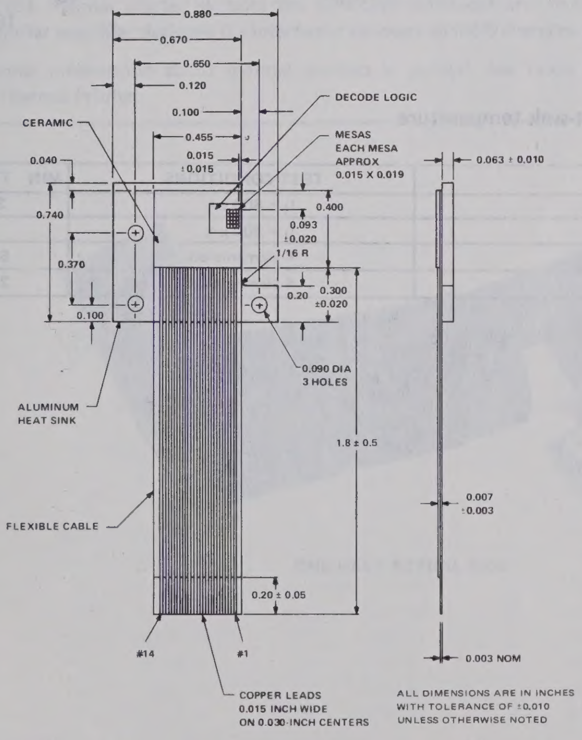
TYPE EPN2100
THERMAL PRINTER

TYPE EPN2100
BULLETIN NO. DL-S 7111555, SEPTEMBER 1971
REVISED OCTOBER 1971

- **Silent Operation**
- **Hard-Copy Printout Using Low-Cost Thermal Paper**
- **Permanent Dry Printing Without the Use of Inks, Ribbons, or Chemicals**
- **Character-by-Character Readout**
- **Small Size and Low Power**
- **Few Mechanical Parts Required**
- **Decode/Driver Circuitry Included on the Same Silicon Chip as the Printer**

description

The EPN2100 thermal printer is a readout/printing device having twenty discrete heating elements (5-row-by-4-column matrix) which can be selectively energized to form permanent characters on thermographic paper. Decode/driver circuitry is included on the same silicon chip which utilizes a row-by-row strobed addressing scheme and is MOS compatible (current controlled). Approximate weight of the printer is 1.9 grams. For additional information, see Texas Instruments Application Report CA163, EPN2100 Thermal Printer.


0.880
0.670
0.650
0.120
0.100
CERAMIC
0.455
0.015
±0.015
DECODE LOGIC
MESAS
EACH MESA
APPROX
0.015 X 0.019
0.063 ± 0.010
0.040
0.740
0.400
0.093
±0.020
1/16 R
0.370
0.20
0.300
±0.020
0.100
0.090 DIA
3 HOLES
ALUMINUM
HEAT SINK
1.8 ± 0.5
0.007
±0.003
FLEXIBLE CABLE
0.20 ± 0.05
#14
#1
0.003 NOM
COPPER LEADS
0.015 INCH WIDE
ON 0.030-INCH CENTERS

ALL DIMENSIONS ARE IN INCHES
WITH TOLERANCE OF ±0.010
UNLESS OTHERWISE NOTED

C4	C3	C2	C1	
4	3	2	1	R1
8	7	6	5	R2
12	11	10	9	R3
16	15	14	13	R4
20	19	18	17	R5

MESAS

TERMINAL ASSIGNMENTS

1	V_{CC}
2	R5
3	C4
4	GND
5	R4
6	C3
7	V_L
8	C2
9	R3
10	R2
11	C1
12	OPEN
13	OPEN
14	R1

TENTATIVE DATA SHEET

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

absolute maximum ratings at (or below) 55°C heat-sink temperature (unless otherwise noted)

Supply Voltage V_{CC} (See Note 1)	15 V
Supply Voltage V_L (See Note 1)	10.2 V
Input Current: Column	2 mA
Row	4 mA
Operating Heat-Sink Temperature	55°C
Storage Temperature Range	−20°C to 70°C

NOTE 1: Voltage values are with respect to ground terminal.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply Voltage V_{CC}	14	14.5	15	V
Supply Voltage V_L	7.8	8.3	10.2	V
Column Input On-State Current	600		2000	μA
Column Input Off-State Current	0		90	μA
Row Input On-State Current	400		4000	μA
Row Input Off-State Current	0		90	μA
Width of Row or Column Input Pulse		12		ms
Time to Print One Character (5 Rows)		60		ms
Delay between Character Prints	48			ms
Pressure		10		psi

operating characteristics at 25°C heat-sink temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Column Input On-State Voltage	$I_I = 600\ \mu A$		3.2	4	V
Row Input On-State Voltage	$I_I = 400\ \mu A$			V_L	V
Peak Current from V_{CC}	4 elements on		600		mA
Average Current from V_{CC}	4 elements on		240		mA

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IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE

EPN2200, EPN2201
THERMAL PRINTHEAD, THERMAL PRINTER INCLUDING DRIVER

EPN2200 . . . THERMAL PRINTHEAD
EPN2201 . . . THERMAL PRINTER

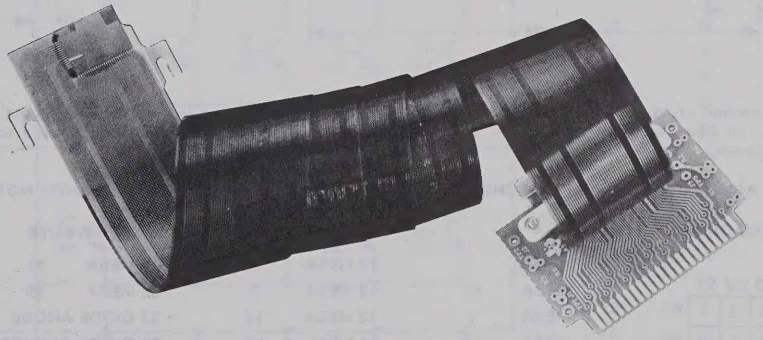
- Silent Operation
- Hard-Copy Printout Using Low-Cost Thermal Paper
- Permanent Dry Printing Without the Use of Inks, Ribbons, or Chemicals
- Character-by-Character Readout
- Small Size and Low Power
- Few Mechanical Parts Required
- Driver Circuitry Provided in 5 Separate 16-Pin Integrated-Circuit Packages

description

The EPN2200 thermal printhead comprises 35 heating elements in a 7-row-by-5 column matrix, a ceramic substrate, a heat sink, and a cable with printed-circuit-card termination. The elements are energized independently to form permanent characters on thermographic paper at the maximum rate of thirty characters per second. The matrix is located on the ceramic in a position which allows immediate reading of the previous line and the previous character printed. Included in the printhead is a temperature-sensing diode for regulating V_{CC} in accordance with temperature variations. The EPN2200 prints a character 100 mils high and 80 mils wide. The cable, consisting of copper strips imbedded in a mylar strip, is approximately three feet long and terminated in a printed-circuit board (part number 954802-001B). The heat sink, cable, and printed-circuit-card termination can be made to the customer's specification.

The EPN2201 thermal printer includes the EPN2200 printhead and five SN21111N drivers. The SN21111N is a 7-channel buffer amplifier designed for interfacing between an MOS character generator and the thermal printhead.

For additional information about thermal printers in general, see Texas Instruments Application Report CA163, EPN2100 Thermal Printer.



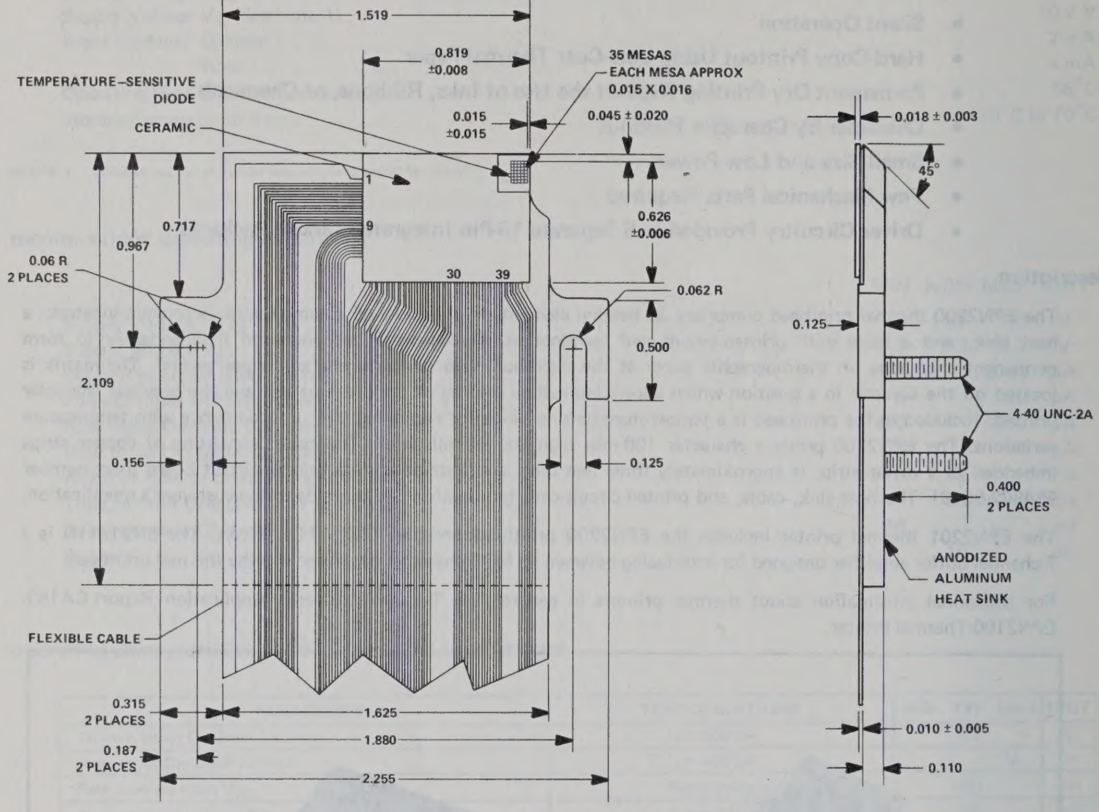
ONE-HALF ACTUAL SIZE

EPN2200, DRIVER ASSEMBLY, AND PRINT SAMPLE

TENTATIVE DATA SHEET

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

mechanical data


1.519
0.819
±0.008
35 MESAS
EACH MESA APPROX
0.015 X 0.016
TEMPERATURE–SENSITIVE
DIODE
CERAMIC
0.015
±0.015
0.045 ± 0.020
0.018 ± 0.003
45°
1
9
0.717
0.967
0.626
±0.006
0.06 R
2 PLACES
30
39
0.062 R
0.125
0.500
2.109
4-40 UNC-2A
0.156
0.125
0.400
2 PLACES
ANODIZED
ALUMINUM
HEAT SINK
FLEXIBLE CABLE
0.315
2 PLACES
1.625
1.880
0.187
2 PLACES
2.255
0.010 ± 0.005
0.110

White portion of 42-lead flexible cable is copper strip embedded in mylar. Leads numbered 1, 9, 30, and 39 are 2-oz copper, all other leads are 1-oz copper. 42-lead cable is shown truncated as termination is made to the customer's specification.

ALL DIMENSIONS ARE IN INCHES WITH TOLERANCE OF ±0.010 UNLESS OTHERWISE NOTED

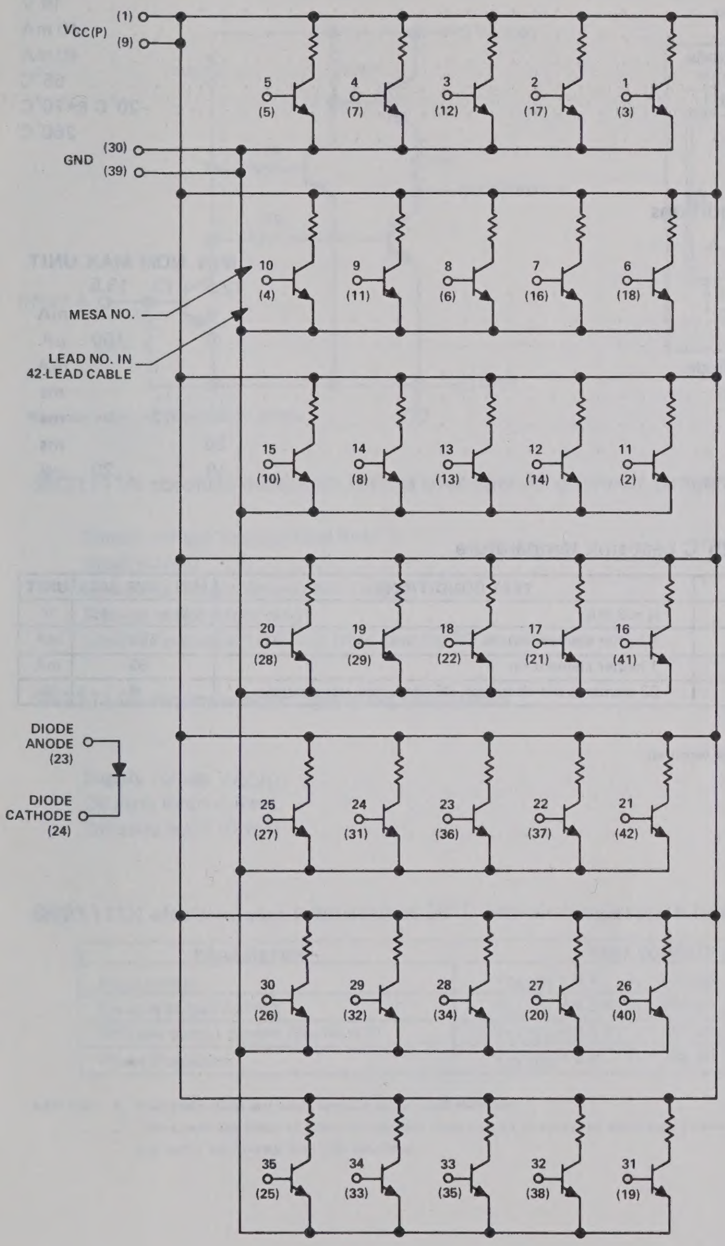
MESAS AND DIODE

	C5	C4	C3	C2	C1	
	5	4	3	2	1	R1
	10	9	8	7	6	R2
	15	14	13	12	11	R3
	20	19	18	17	16	R4
D	25	24	23	22	21	R5
	30	29	28	27	26	R6
	35	34	33	32	31	R7

PRINTHEAD TERMINAL ASSIGNMENTS

1	$V_{CC(P)}$		11	MESA	9	21	MESA	17	31	MESA	24
2	MESA	11	12	MESA	3	22	MESA	18	32	MESA	29
3	MESA	1	13	MESA	13	23	DIODE ANODE		33	MESA	34
4	MESA	10	14	MESA	12	24	DIODE CATHODE		34	MESA	28
5	MESA	5	15	NOT USED		25	MESA	35	35	MESA	33
6	MESA	8	16	MESA	7	26	MESA	30	36	MESA	23
7	MESA	4	17	MESA	2	27	MESA	25	37	MESA	22
8	MESA	14	18	MESA	6	28	MESA	20	38	MESA	32
9	$V_{CC(P)}$		19	MESA	31	29	MESA	19	39	GROUND	
10	MESA	15	20	MESA	27	30	GROUND		40	MESA	26
									41	MESA	16
									42	MESA	21

EPN2200 schematic


$V_{CC(P)}$
(1)
(9)
GND
(30)
(39)
5 (5)
4 (7)
3 (12)
2 (17)
1 (3)
10 (4)
9 (11)
8 (6)
7 (16)
6 (18)
MESA NO.
LEAD NO. IN 42-LEAD CABLE
15 (10)
14 (8)
13 (13)
12 (14)
11 (2)
20 (28)
19 (29)
18 (22)
17 (21)
16 (41)
DIODE ANODE (23)
DIODE CATHODE (24)
25 (27)
24 (31)
23 (36)
22 (37)
21 (42)
30 (26)
29 (32)
28 (34)
27 (20)
26 (40)
35 (25)
34 (33)
33 (35)
32 (38)
31 (19)

Both $V_{CC(P)}$ leads and both ground leads must be used.

TABLE OF CONNECTIONS FROM PRINTHEAD TERMINATED IN PRINTHEAD CARD NO. 954802-0001B

CONNECTOR BOARD		PRINTHEAD
PIN NO.	SIDE	
1	A	MESA 16
1	B	MESA 21
2	A	GND
2	B	MESA 26
3	A	MESA 22
3	B	MESA 32
4	A	MESA 33
4	B	MESA 23
5	A	MESA 34
5	B	MESA 28
6	A	MESA 24
6	B	MESA 29
7	A	MESA 19
7	B	GND
8	A	MESA 25
8	B	MESA 20
9	A	MESA 35
9	B	MESA 30
10	A	DIODE ANODE
10	B	DIODE CATHODE
11	A	MESA 17
11	B	MESA 18
12	A	MESA 31
12	B	MESA 27
13	A	MESA 2
13	B	MESA 6
14	A	NOT USED
14	B	MESA 7
15	A	MESA 13
15	B	MESA 12
16	A	MESA 9
16	B	MESA 3
17	A	$V_{CC(P)}$
17	B	MESA 15
18	A	MESA 4
18	B	MESA 14
19	A	MESA 5
19	B	MESA 8
20	A	MESA 1
20	B	MESA 10
21	A	$V_{CC(P)}$
21	B	MESA 11
22	A	NOT USED
22	B	NOT USED

EPN2200 absolute maximum ratings at (or below) 55°C heat-sink temperature (unless otherwise noted)

Supply voltage $V_{CC(P)}$ (See Note 1)	19 V
Input current to heater element	40 mA
Input current to temperature-sensing diode	40 mA
Operating heat-sink temperature	55°C
Storage temperature range	–20°C to 70°C
Lead temperature for 5 seconds	260°C

EPN2200 recommended operating conditions

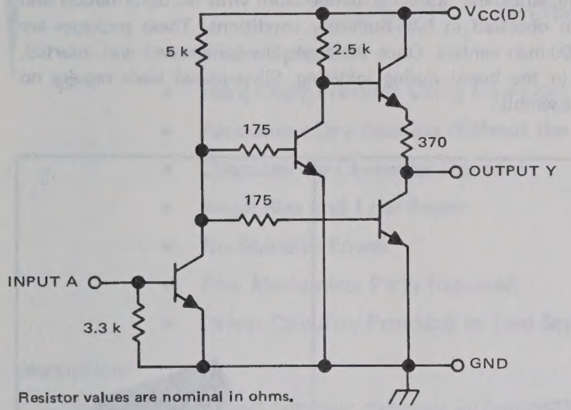
	MIN	NOM	MAX	UNIT
Supply voltage $V_{CC(P)}$ (See Note 1)	12.5	13	13.5	
On-state input current	8			mA
Off-state input current	0		100	µA
Input current to temperature sensing diode		1		mA
Width of input pulse to heater element		12		ms
Time to print one character		12		ms
Delay between character prints	20			ms
Pressure	10		20	psi

EPN2200 electrical characteristics at 25°C heat-sink temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Heater element input voltage	I_I = 8 mA	0.8		1.2	V
Peak current from $V_{CC(P)}$	1 heater element on		150		mA
Steady-state current from $V_{CC(P)}$	1 heater element on		50		mA
Average power dissipation	22 elements per character, 30 characters per second		6		W

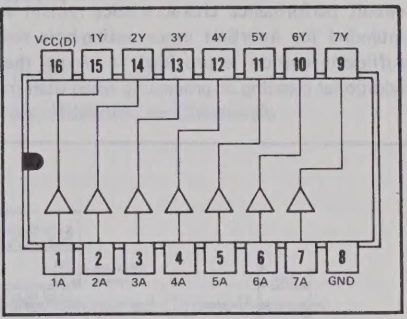
NOTE 1: Voltage values are with respect to ground terminal.

SN21111N schematic (each driver)



Resistor values are nominal in ohms.

N
DUAL-IN-LINE PACKAGE (TOP VIEW)



SN21111N absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC(D)}$ (See Note 1)	7 V
Input current	4 mA
Operating free-air temperature range	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1/16 inch from case for 10 seconds	260°C

SN21111N recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage $V_{CC(D)}$	4.5	5	5.5	V
On-state input current	700		2000	μA
Off-state input current	0		100	μA

SN21111N electrical characteristics at 25°C free-air temperature (unless otherwise noted)

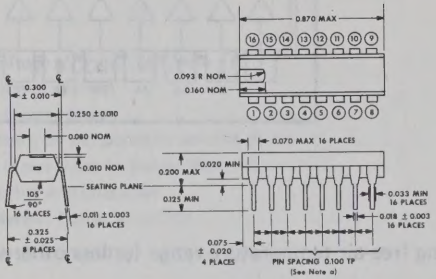
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage	$V_{CC(D)} = 5$ V, $I_I = 700$ μA			1	V
On-state output current	$V_{CC(D)} = 4.5$ V, $I_I = 700$ μA, $V_O = 1.2$ V	−10			mA
Off-state output current (See Note 2)	$V_{CC(D)} = 5.5$ V, $I_I = 100$ μA, $V_O = 0.5$ V			−10	μA
Power dissipation	$V_{CC(D)} = 5$ V, $I_I = 700$ μA		100		mW

NOTES: 1. Voltage values are with respect to ground terminal.

2. The specified limit applies for current flow out of the output terminal. When tested with 0.5 V applied to the output, current will normally be forced into the terminal.

MECHANICAL DATA FOR SN21111N DRIVER

This dual-in-line package consists of a circuit mounted on a 16-lead frame and encapsulated within an electrically nonconductive, plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics remain stable when operated in high-humidity conditions. These packages are intended for insertion in mounting-hole rows on 0.300-inch centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Silver-plated leads require no additional cleaning or processing when used in soldered assembly.


0.870 MAX
16
15
14
13
12
11
10
9
0.093 R NOM
0.160 NOM
1
2
3
4
5
6
7
8
0.300
± 0.010
0.250 ± 0.010
0.080 NOM
0.010 NOM
SEATING PLANE
105°
90°
16 PLACES
0.011 ± 0.003
16 PLACES
0.325
± 0.025
8 PLACES
0.070 MAX 16 PLACES
0.020 MIN
0.200 MAX
0.125 MIN
0.033 MIN
16 PLACES
0.018 ± 0.003
16 PLACES
0.075
± 0.020
4 PLACES
PIN SPACING 0.100 TP
(See Note a)

NOTES:
a. Each pin centerline is located within 0.010 of its true longitudinal position.
b. All dimensions are in inches unless otherwise noted.

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TYPES EPN2300, EPN2301
THERMAL PRINTHEAD, THERMAL PRINTER INCLUDING DRIVERS

EPN2300 . . . THERMAL PRINTHEAD

EPN2301 . . . THERMAL PRINTER

- **Silent Operation**
- **Hard-Copy Printout Using Low-Cost Thermal Paper**
- **Permanent Dry Printing Without the Use of Inks, Ribbons, or Chemicals**
- **Character-by-Character Readout**
- **Small Size and Low Power**
- **No Standby Power**
- **Few Mechanical Parts Required**
- **Driver Circuitry Provided in Two Separate 14-Pin Integrated-Circuit Packages**

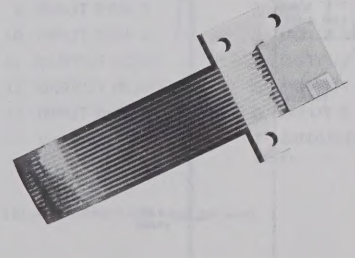
description

The EPN2300 thermal printhead comprises 20 heating elements in a 5-row-by-4-column matrix, a ceramic substrate, a heat sink, and a cable. The elements are selectively energized to form permanent characters on thermographic paper at the maximum rate of 12 characters per second. Information is addressed to the thermal printhead by selecting one row, energizing the appropriate columns in that row depending on the character to be printed, and then proceeding to the next row (row-by-row strobing). The matrix is located on the ceramic in a position which allows immediate reading of the previous line and the previous character printed. The EPN2300 prints a character 100 mils in height and 64 mils in width and weighs approximately 1.9 grams.

The EPN2301 thermal printer includes the EPN2300 printhead, one SN21485N row driver, and one SN21484N column driver. The drivers are designed for interfacing between an MOS character generator and the thermal printhead.

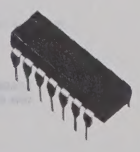
These devices are particularly suited for battery operation since neither the drivers nor the printhead consume power except when printing.

For additional information about thermal printers in general, see Texas Instruments Application Report CA163, EPN2100 Thermal printer.



EPN2300 AND PRINT SAMPLE

SN21485



SN21484

TENTATIVE DATA SHEET

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

TYPES EPN2300, EPN2301
THERMAL PRINTHEAD, THERMAL PRINTER INCLUDING DRIVERS

EPN2300 absolute maximum ratings at (or below) 55°C heat-sink temperature (unless otherwise noted)

Supply voltage $V_{CC(P)}$ (See Note 1)	17 V
Row input current with one column on	40 mA
Operating heat-sink temperature	55°C
Storage temperature range	−20°C to 70°C
Lead temperature for 5 seconds	260°C

EPN2300 recommended operating conditions

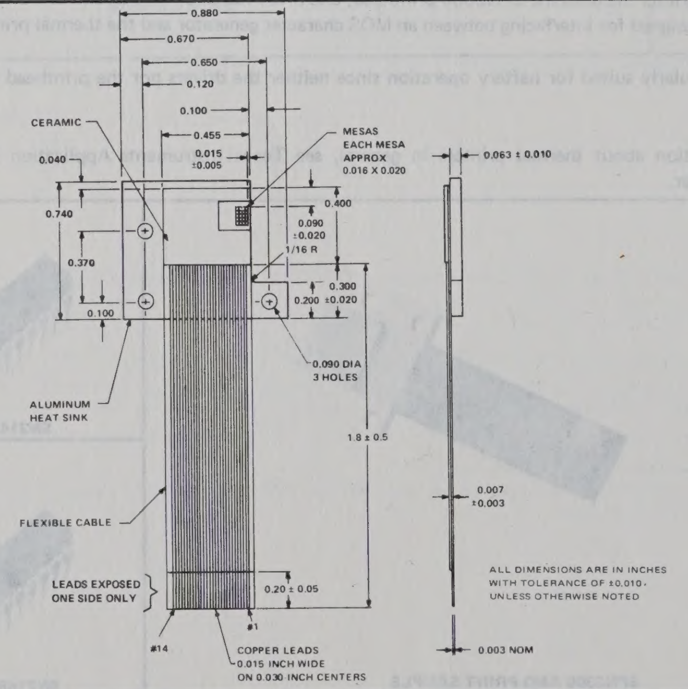
	MIN	NOM	MAX	UNIT
Supply voltage $V_{CC(P)}$ (See Note 1)	14	14.5	15	V
Input current to selected row with one column on	8			mA
Input current to nonselected row	0		100	µA
Width of row input pulse		12		ms
Time to print one character (5 rows)		60		ms
Delay between character prints	20			ms
Pressure	6		15	psi

EPN2300 electrical characteristics at 25°C heat-sink temperature, $V_{CC(P)}$ = 14.5 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Row-to-column on-state voltage	1 column on, row input current = 8 mA			2.6	V
Peak current from $V_{CC(P)}$	1 heater element on		160		mA
Steady-state current from $V_{CC(P)}$	1 heater element on		60		mA
Average power dissipation	12 elements per character, 12 characters per second		1.4		W

NOTE 1: Supply voltage values assume the use of an SN21485 driver and are with respect to the ground terminal of the SN21485.

EPN2300 mechanical data


0.880
0.670
0.650
0.120
0.100
CERAMIC
0.455
0.015
±0.005
0.040
MESAS
EACH MESA
APPROX
0.016 X 0.020
0.063 ± 0.010
0.740
0.400
0.090
±0.020
1/16 R
0.370
0.300
0.200 ±0.020
0.100
0.090 DIA
3 HOLES
ALUMINUM
HEAT SINK
1.8 ± 0.5
0.007
±0.003
FLEXIBLE CABLE
LEADS EXPOSED
ONE SIDE ONLY
0.20 ± 0.05
#1
#14
COPPER LEADS
0.015 INCH WIDE
ON 0.030 INCH CENTERS
0.003 NOM

ALL DIMENSIONS ARE IN INCHES WITH TOLERANCE OF ±0.010, UNLESS OTHERWISE NOTED

C4	C3	C2	C1	
4	3	2	1	R1
8	7	6	5	R2
12	11	10	9	R3
16	15	14	13	R4
20	19	18	17	R5

MESAS

TERMINAL ASSIGNMENTS

1	C1
2	R5
3	R4
4	R3
5	OPEN
6	C4
7	OPEN
8	C2
9	C3
10	R1
11	R2
12	OPEN
13	V_{CC}
14	OPEN

SN21485 and SN21484 absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC(D)}$ (See Note 2)	10 V
Off-state output voltage of SN21484 column driver	17 V
Input current	4 mA
Operating free-air temperature range	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1/16 inch for case for 10 seconds	260°C

SN21485 and SN21484 recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage $V_{CC(D)}$	7	8	9	V
On-state input current	500		2000	μA
Off-state input current	0		100	μA

NOTE 2: All voltage values for the drivers are with respect to their ground terminals.

SN21485 row driver electrical characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage	$V_{CC(D)} = 8$ V, $I_I = 500$ μA, $V_O = 3.1$ V			4.6	V
On-state output current	$V_{CC(D)} = 7$ V, $I_I = 500$ μA, $V_O = 3.1$ V	−40			mA
Off-state output current (see Note 3)	$V_{CC(D)} = 9$ V, $I_I = 100$ μA, $V_O = 0.8$ V			−10	μA
Average power dissipation	12 elements per character, 12 characters per second		175		mW

NOTE: 3. The specified limit applies for current flow out of the output terminal. When tested with 0.8 V applied to the output, current will normally be forced into the terminal.

SN21484 column driver electrical characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage	$V_{CC(D)} = 8$ V, $I_I = 500$ μA			2.6	V
On-state output voltage	$V_{CC(D)} = 9$ V, $I_I = 500$ μA, $I_O = 160$ mA			0.5	V
Off-state output current	$V_{CC(D)} = 9$ V, $I_I = 100$ μA, $V_O = 17$ V			100	μA
Average power dissipation	12 elements per character, 12 characters per second		100		mW

PIN CONNECTIONS FOR SN21485 ROW DRIVER

1	NC	8	NC
2	INPUT ROW 1	9	INPUT ROW 3
3	OUTPUT ROW 1	10	INPUT ROW 4
4	OUTPUT ROW 2	11	OUTPUT ROW 4
5	INPUT ROW 2	12	OUTPUT ROW 5
6	OUTPUT ROW 3	13	INPUT ROW 5
7	GROUND	14	$V_{CC(D)}$

PIN CONNECTIONS FOR SN21484 COLUMN DRIVER

1	GROUND†	8	GROUND†
2	NC	9	INPUT C
3	INPUT A	10	OUTPUT C
4	OUTPUT A	11	OUTPUT D
5	OUTPUT B	12	INPUT D
6	INPUT B	13	GROUND†
7	GROUND†	14	$V_{CC(D)}$

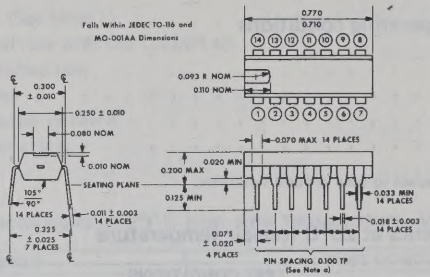
NC—No internal connection

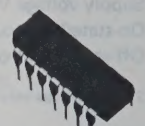
†Only one of the ground pins (1, 7, 8, or 13) of the SN21484 need be used.

SN21485 and SN21484 mechanical data

This dual-in-line package consists of a circuit mounted on a 14-lead frame and encapsulated within an electrically nonconductive, plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics remain stable when operated in high-humidity conditions. These packages are intended for insertion in mounting-hole rows on 0.300-inch centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Silver-plated leads require no additional cleaning or processing when used in soldered assembly.

14-PIN N PLASTIC DUAL-IN-LINE PACKAGE OUTLINE

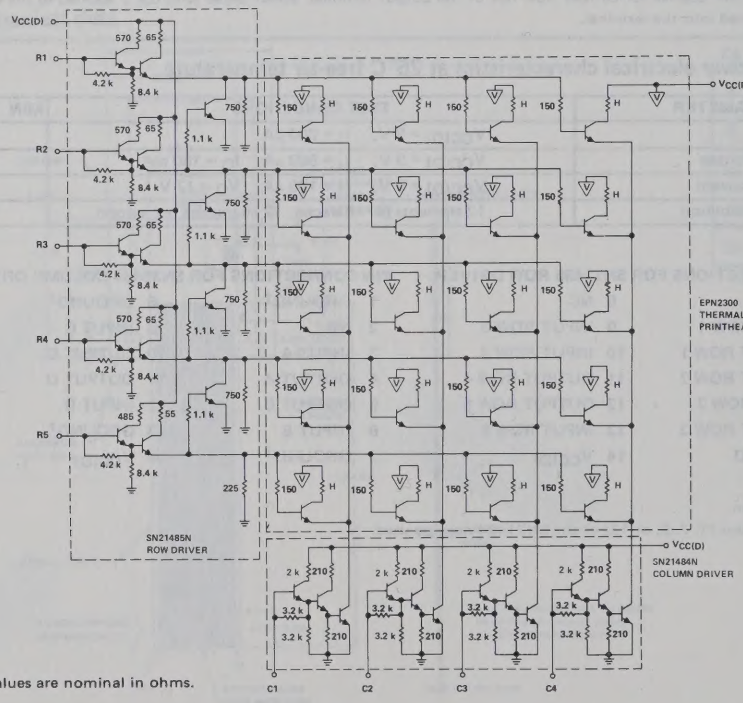

Falls Within JEDEC TO-116 and
MO-001AA Dimensions
0.770
0.710
⑭ ⑬ ⑫ ⑪ ⑩ ⑨ ⑧
① ② ③ ④ ⑤ ⑥ ⑦
0.093 R NOM
0.110 NOM
0.300 ± 0.010
0.250 ± 0.010
0.080 NOM
0.010 NOM
SEATING PLANE
105° / 90°
14 PLACES
0.011 ± 0.003
14 PLACES
0.325 ± 0.025
7 PLACES
0.070 MAX 14 PLACES
0.020 MIN
0.200 MAX
0.125 MIN
0.033 MIN
14 PLACES
0.018 ± 0.003
14 PLACES
0.075 ± 0.020
4 PLACES
PIN SPACING 0.100 TP
(See Note a)



NOTES: a. Each pin centerline is located within 0.010 of its true longitudinal position.

b. All dimensions are in inches unless otherwise noted.

schematic of drivers and printhead


VCC(D)
R1
R2
R3
R4
R5
570
65
485
55
4.2 k
8.4 k
750
1.1 k
225
150
H
VCC(P)
EPN2300
THERMAL
PRINTHEAD
SN21485N
ROW DRIVER
VCC(D)
SN21484N
COLUMN DRIVER
2 k
210
3.2 k
C1
C2
C3
C4

NOTE: Resistor values are nominal in ohms.

▽ . . . $V_{CC(P)}$ bus

⦚H . . . Heater element

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME
IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE

EPN2100 THERMAL PRINTER

Thomas R. Payne

Texas Instruments has developed solid state thermal printers for use as readout/printing devices in a wide variety of applications. One of these devices, the EPN2100 Thermal Printer, is presently in production and available for sale. Other Thermal Printers in the Texas Instruments EPN series are presently in the design state.

A thermal printer offers many distinct benefits. It operates silently with hard copy printout without using inks, ribbons or odorous chemicals. It provides character-by character readout with the last printed character visible immediately. The thermal printer has the additional advantages of high speed output, small size and low power requirements. Because few mechanical parts are needed, overall mechanical design is simplified greatly. In addition, the EPN2100 Thermal Printer has decoding and drive circuitry on the same chip as the actual heating elements reducing logic interface costs. Thermographic paper used with thermal printers is manufactured by a number of companies, including 3M and NCR.

This application report provides a general description of the thermal printer and a detailed discussion of the EPN2100 Thermal Printer and its necessary interface requirements. Figure 1 shows a photograph of Texas Instruments EPN2100 Thermal Printer with a print sample.

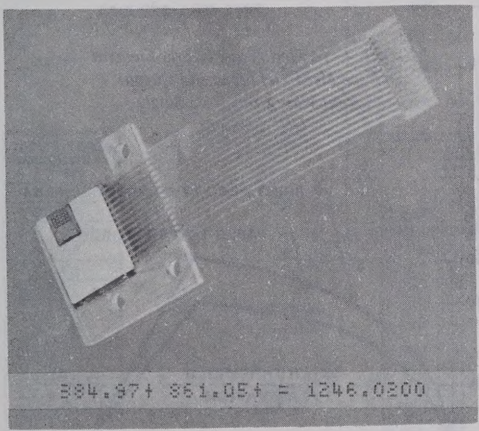


FIGURE 1. Texas Instruments EPN2100 Thermal Printer and Print Sample

GENERAL DESCRIPTION

A thermal printer is a printing apparatus which uses thermal energy rather than impact energy as its printing method. The heart of the thermal printer is the thermal printhead which contains a matrix of heating elements, each of which consists of a single crystalline semiconductor body in a mesa shape. Each mesa contains a transistor-resistor pair, selectively energized so that the power dissipated by the resistor causes the top surface of the selected mesa to become hot. This mesa surface then produces a permanent localized dot on thermally sensitive paper which is pressed against it. By selectively energizing different groups of heater elements, different groups of dots can be formed on the thermally sensitive paper defining alphanumeric characters. To print an "E", for example, the shaded elements are energized in the printhead as shown in Figure 2.

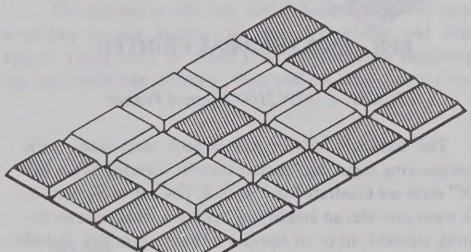


FIGURE 2. Heat Elements Energized to Print an "E"

The arrangement of the EPN2100 Thermal Printer is shown in Figure 3. Each heater mesa in the thermal printhead matrix is a separate piece of silicon approximately 1.5 mils thick and 17 mils by 13 mils. The mesas comprising the heater element array are thermally isolated from each other to produce sharp, well defined dot printouts. Electrical connection to the heater elements is made by a metallic connecting pattern running beneath the mesas which connects with the decoding logic on the same chip. The thermal printhead is mounted to a ceramic support with a metallized pattern on the back side. Electrical connection is made by bonding from the back side of the silicon chip through a slot in the ceramic to the metallization pattern on the ceramic. Since the leads and interconnections of the printhead circuit are between the silicon chip and ceramic support, they are not exposed, resulting in a high-reliability structure. A mylar cable is soldered to the ceramic which is used for external connections. The ceramic is mounted to an aluminum heatsink.

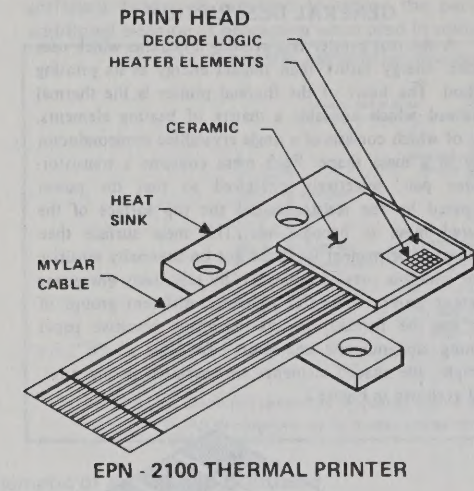


FIGURE 3. EPN2100 Thermal Printer

The transistor-resistor pair in each mesa along with accompanying input and output current waveforms for the "ON" state are illustrated in Figure 4. The active element in each mesa provides an amplifying function which allows the heating element array to operate directly from low power driving sources. Typically, the resistor is connected to a positive voltage source, V_{CC}, of about 15 V, the emitter is tied to ground or a voltage source very close to ground, and the base to a drive circuit which acts as a current source in the "ON" state and low impedance sink in the "OFF" state. Because silicon has a positive temperature coefficient, resistance is lowest during the first part of the print pulse when the mesa is cold. This resistance increases as the mesa heats up. Consequently, power dissipation is greatest at the beginning of the print cycle when it is needed the most and decreases as the mesa gets hotter. The energy dissipation for a single element print is approximately 100 millijoules. The maximum duty cycle and power dissipation depends on the thermal printer application.

Figure 5 indicates the temperature of an energized mesa and the corresponding temperature of the paper in contact with the mesa. The thermal printer and paper must mate with a pressure of approximately 10 psi for adequate printing density considering the characteristics of paper available presently. A number of different pressure pads have been used including pads fabricated of felt, Teflon, and BeCu. When the paper temperature exceeds its threshold of approximately 110°C a black dot begins to form. Because of the thermal coupling required between the energized mesa and paper, it is necessary to heat the mesa to a higher temperature. The maximum peak temperature of an energized mesa is typically between 175°C and 250°C.

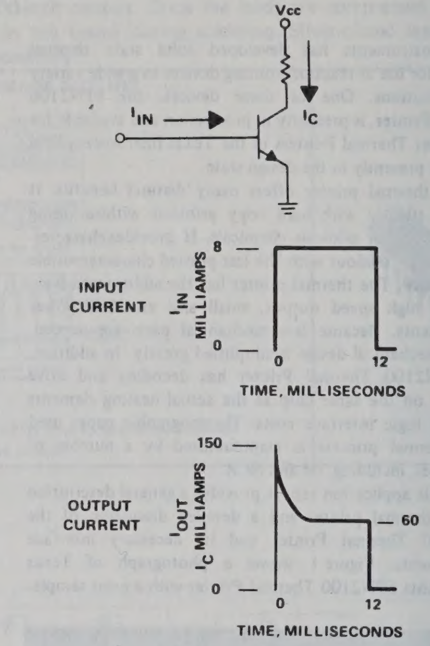


FIGURE 4. (A) Individual Heater Element in Each Mesa (B) Input and Output Current Waveforms for a Single "ON" Element

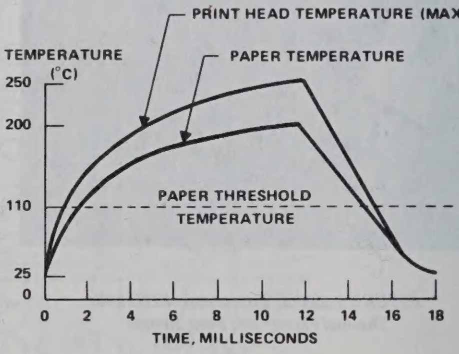


FIGURE 5. Thermal Graph of an Energized Mesa and the Corresponding Temperature of the Paper in Contact with the Mesa

It is necessary in application to have the thermal printer attached to a heat sink system which can dissipate the energy produced. The amount of energy will depend on the maximum duty cycle applied. In worse case design it is necessary to assume that the heat sink must dissipate 75% of the energy produced by the thermal printer.

EPN2100 THERMAL PRINTER

General Description

The EPN2100 Thermal Printer is shown in Figure 6. The printhead includes twenty distinct mesas organized in a 5 X 4 matrix of five rows and four columns with the necessary decode logic on the same chip.

Each mesa is 17 mils high by 13 mils wide with approximately 3 mils separation between mesas. This results in a total character height of 100 mils and width of 64 mils. The mylar cable contains 14 copper leads of which 12 are used: five row logic signals, four column logic signals, two separate voltage lines, and one ground line.

Timing Requirements

The EPN2100 Thermal Printer uses an X-Y (Row – Column) addressing scheme to allow for a simple addressing, decoding, and driving scheme between the thermal printer and external logic. Using a Row – Column addressing technique allows sharing of one Read Only Memory (ROM) character generator to print all of the different characters. In addition, only nine logic signals are required for a twenty dot array keeping the number of pin connections to a minimum.

To form alphanumeric characters with the EPN2100 Thermal Printer a technique called "strobing" is utilized. This technique is basically time-sharing of information across the rows; one row at a time. Information is addressed to the thermal printer by selecting one row, energizing the appropriate columns in that row depending on the character to be printed, and then proceeding to the next row. After all of the rows have been selected, the paper is moved and the process repeated to print the next character.

Figure 7 illustrates the necessary timing requirements to print an "E" and a "4". As can be seen, it takes 60 milliseconds to print one complete character before the paper is moved to print the next character. There is no strobing of either the V_L or V_{CC} voltage lines.

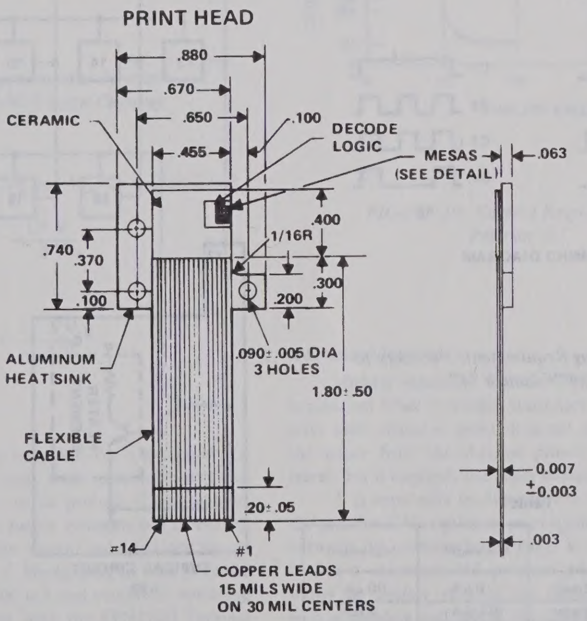
Logic Interface

A circuit schematic of the EPN2100 Thermal Printer, including both the decode logic and heater mesas, is shown in Figure 8. The decode logic is current controlled with the necessary current drive requirements for the row and column inputs shown in Table I.

The voltage at the row and column inputs will vary according to the amount of current available and this voltage swing must be taken into account when designing the logic interface circuitry. With 600 μA input current the

INPUT TERM	
# 1	Vcc
# 2	R5
# 3	C4
# 4	GND.
# 5	R4
# 6	C3
# 7	V_L
# 8	C2
# 9	R3
#10	R2
#11	C1
#12	OPEN
#13	OPEN
#14	R1

ALL DIMENSION
IN INCHES
WITH TOLERANCES OF
± 0.010
UNLESS OTHERWISE NOTED



C4	C3	C2	C1	
4	3	2	1	R1
8	7	6	5	R2
12	11	10	9	R3
16	15	14	13	R4
20	19	18	17	R5

MESAS

FIGURE 6. Mechanical Layout of the EPN2100 Thermal Printer

voltage at the column inputs will increase to a maximum of 3.5 V and continue to rise to approximately 6 V at 2 mA input current. The voltage at the row inputs will increase to approximately the value of V_L for all values of input current between 600 μA and 2 mA. In the "O" state the voltage at the column inputs can rise to a maximum of 1.2 V while the row input voltage can swing anywhere between 3 V and V_L.

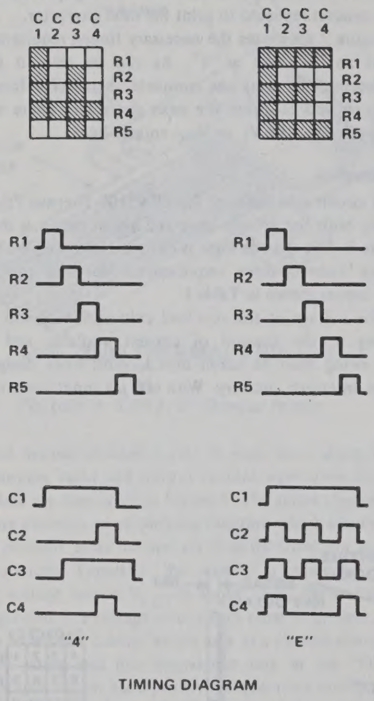
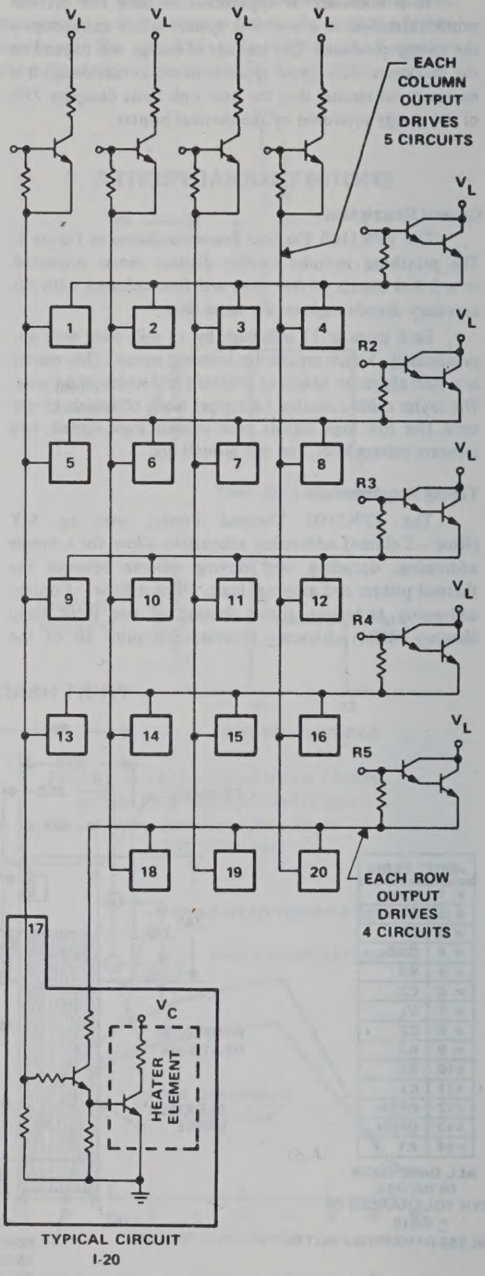

C C C C
1 2 3 4
R1
R2
R3
R4
R5
C C C C
1 2 3 4
R1
R2
R3
R4
R5
R1
R2
R3
R4
R5
R1
R2
R3
R4
R5
C1
C2
C3
C4
C1
C2
C3
C4
"4"
"E"
TIMING DIAGRAM

FIGURE 7. Timing Requirements Necessary to Print an "E" and a "4"

Table I

		Minimum	Maximum
Column	"0" State	0 μA	90 μA
Driver	"1" State	600 μA	2 mA
Row	"0" State	0 μA	90 μA
Driver	"1" State	400 μA	4 mA


V_L
V_L
V_L
V_L
EACH COLUMN OUTPUT DRIVES 5 CIRCUITS
V_L
R1
V_L
R2
V_L
R3
V_L
R4
V_L
R5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
EACH ROW OUTPUT DRIVES 4 CIRCUITS
V_C
HEATER ELEMENT
TYPICAL CIRCUIT
I-20

EPN 2100 CIRCUIT SCHEMATIC

FIGURE 8. Circuit Schematic of the EPN 2100

One recommended interface application is to use Metal Oxide Semiconductor (MOS) logic circuitry as shown in Figure 9.

Texas Instruments fabricates a special MOS chip, TMS1732, which is applicable for the EPN2100 Thermal Printer. A special advantage of this chip is that V_{SS} is the same magnitude as V_{CC} which eliminates one power supply. If bipolar transistors are used, it is recommended that the interface circuit have a high output impedance.

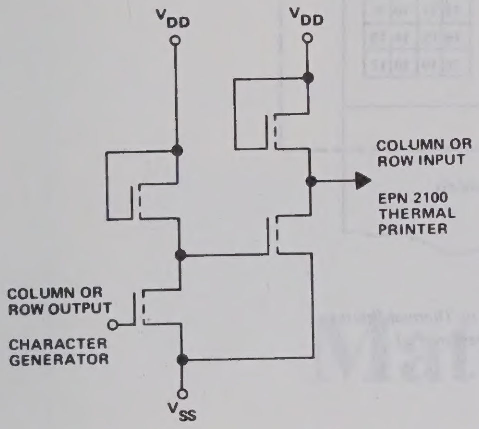


FIGURE 9. One Recommended Interface Application is Using MOS Logic Circuitry

The voltage margins on V_L and V_{cc} for the EPN2100 Thermal Printer are:

$$V_L = 8.3\text{ V}\,\frac{+\,1.9\text{ V}}{-\ \ .5\text{ V}}$$

$$V_{cc} = 14.5\text{ V}\,\frac{+\ \ .5\text{ V}}{-\ \ .5\text{ V}}$$

Power Requirements

During any print cycle only one row is energized at a time with between one and four columns energized depending on the character to be printed. Consequently, there is a maximum of four heater elements out of twenty "ON" at any given time. The current pulse for one heater element was given in Figure 5. Multiplying by four gives the maximum peak current of 600 mA and maximum operating current of 240 mA required with the EPN2100 Thermal Printer. Figure 10 shows the current waveforms when printing an "E". During R1 and R5 print times, all four columns are energized and four heater transistors are "ON". During R3 print time, three columns are energized and three transistors are "ON". During R2 and and R4 print times only one column is energized and one heater transistor is "ON". After printing a complete character, it is necessary for the thermal printer to cool for a minimum of four clock times (48 milliseconds), during which time the paper can be moved, before printing the next character. The maximum printing rate, therefore, is 9.3 characters per second, or 108 msec per character print.

During random printing of characters approximately 60% of the heater elements are energized during each print cycle. Applying this rate and the maximum printing speed, the average power dissipation for the EPN2100 Thermal Printer is 1.4 watts. It is necessary to attach an external heatsink to the thermal printer which can dissipate 75% of the power generated while keeping the back side of the thermal printer aluminum heatsink below 55°C.

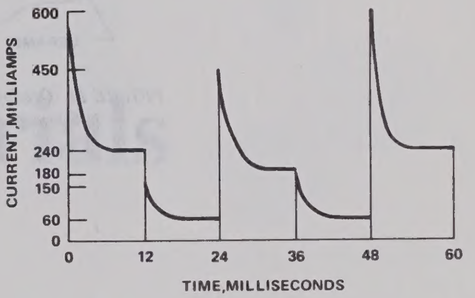


FIGURE 10. Current Requirements to Print an "E"

Mechanical Interface

Highest reliability for the EPN2100 Thermal Printer is achieved when it remains stationary and the paper moved after each character print. It is not necessary to disengage the paper from the thermal printer during this time of travel, but if engaged, the paper should be kept flush.

It is imperative for the paper to be lined up parallel to the printhead for optimum print quality. The ideal pressure between the printhead and paper is 10 psi, ± 0.5 psi, with felt as a recommended pressure pad material. Figure 11 shows an overlay view of the thermal printer in contact with a pressure pad where the dimensions are such that a total force of 90 grams, ± 5 grams, is required to produce the correct pressure.

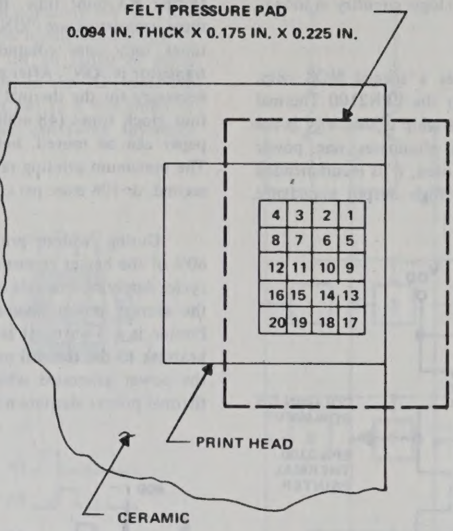

FELT PRESSURE PAD
0.094 IN. THICK X 0.175 IN. X 0.225 IN.
4
3
2
1
8
7
6
5
12
11
10
9
16
15
14
13
20
19
18
17
PRINT HEAD
CERAMIC

FIGURE 11. Overlay View of Thermal Printer in Contact with a Pressure Pad

Materials

12

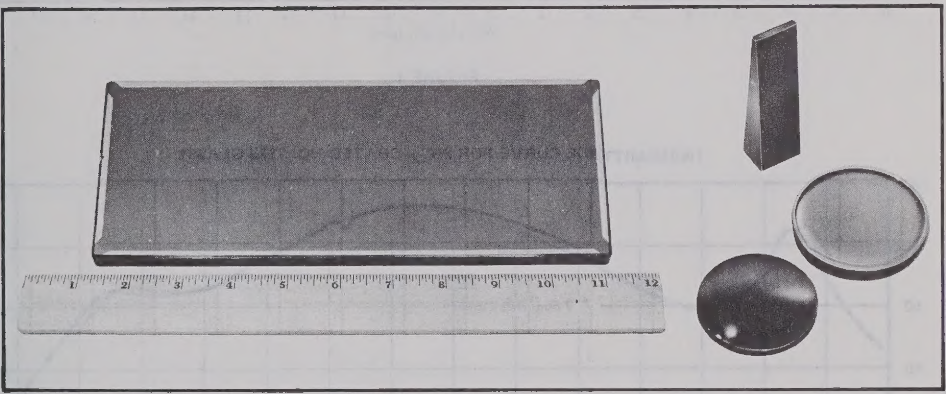
NO. 1173 INFRARED TRANSMITTING CHALCOGENIDE GLASS

NO. 1173 INFRARED TRANSMITTING CHALCOGENIDE GLASS
BULLETIN NO. DL-S 691217, MARCH 1969

DESIGNED FOR WINDOWS, LENSES, DOMES, AND OTHER OPTICAL ELEMENTS IN INFRARED SYSTEMS

- Compatible with any Optical System Operational within the 0.8-μm to 15-μm Region
- Available in Sizes up to 12 in. x 24 in.
- Offered in Cast Blanks, or Optically Ground, Polished, and Coated Elements
- Casting Characteristics Make Glass Suitable for Larger Sizes and Various Shapes

typical configurations



physical characteristics at 25°C (unless otherwise noted)

Knoop Hardness (50-Gram Load)	150
Density	4.67 gms/cc
Expansion Coefficient	15 x $10^{-6}/^{\circ}C$
Modulus of Elasticity	3.1 x 10^{-6} psi
Modulus of Rupture for Annealed Glass	1500 to 3000 psi
Modulus of Rupture for Tempered Glass	7000 to 10,000 psi
Poisson's Ratio	0.25
Thermal Conductivity	0.00072 $\mathrm{cal} \cdot \mathrm{sec}^{-1} \cdot \mathrm{cm}^{-1} \cdot {}^{\circ}\mathrm{C}^{-1}$
Viscosity Strain Point (Viscosity = $10^{14.6}$ Poise)	240°C
Viscosity Anneal Point (Viscosity = $10^{13.4}$ Poise)	259°C
Viscosity Softening Point (Viscosity = $10^{7.6}$ Poise)	370°C

maximum recommended operating temperatures

Annealed Glass	200°C
Tempered Glass	175°C

NO. 1173 INFRARED TRANSMITTING CHALCOGENIDE GLASS

TYPICAL OPTICAL CHARACTERISTICS

TRANSMITTANCE CURVES FOR UNCOATED NO. 1173 GLASS

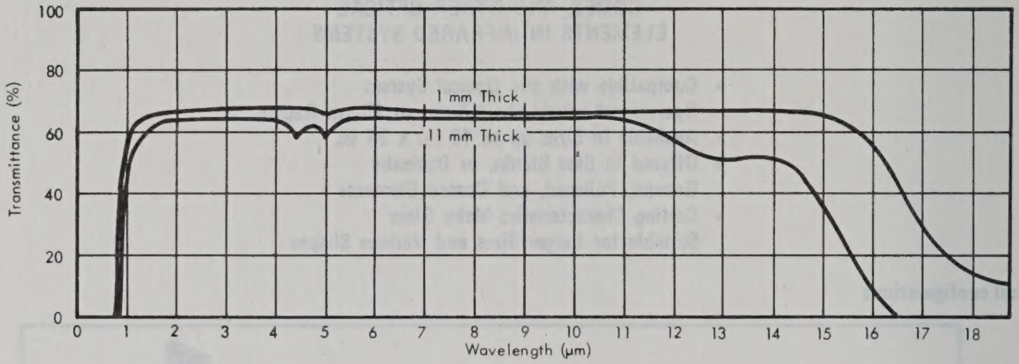


FIGURE 1

TRANSMITTANCE CURVE FOR PbF_2–COATED NO. 1173 GLASS†

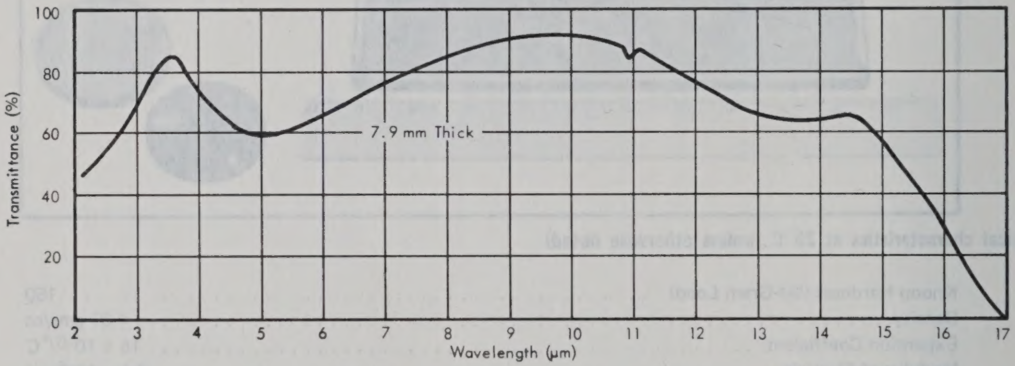


FIGURE 2

INDEXES OF REFRACTION FOR NO. 1173 GLASS AT 25°C

WAVELENGTH	REFRACTIVE INDEX	WAVELENGTH	REFRACTIVE INDEX	WAVELENGTH	REFRACTIVE INDEX
1 μm	2.724	5 μm	2.616	9 μm	2.604
2 μm	2.640	6 μm	2.613	10 μm	2.600
3 μm	2.626	7 μm	2.610	11 μm	2.596
4 μm	2.620	8 μm	2.607	12 μm	2.592

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† Other coatings are available which provide up to 90% transmittance peaked at wavelengths chosen between 2 and 14 μm.

TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME
IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE